Sky and TELESCOPE

In This Issue:

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Man and Mars

Sky and TELESCOPE

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LETTERS

Sir:

I have noticed that you have plotted Pluto in the constellation of Leo. In other publications it appears in Cancer. I understand that Pluto stays within each star group approximately 20 years, and when Pluto was discovered it was located in Gemini. How can it move through two constellations during 23 years?

FRANKLIN LOEHDE
11542 65th St.
Edmonton, Alberta

Pluto was discovered 23 years ago near Delta Geminorum. Since it moves about 1½ degrees eastward from each opposition, it crossed into Cancer about 1937. Cancer is only 20 degrees wide in longitude, therefore Pluto crossed it in about 14 years and has been in Leo for several years now. It may remain for as long as 30 years in Virgo, which is about 45 degrees wide in longitude. The average for all the zodiacal constellations is about 20 years for Pluto, but this figure cannot be used for every one of them. E. O.

Sir:

Presenting a realistic unit in astronomy is often difficult for the teacher on the upper elementary or junior high school level. It is not always possible to get administrative approval for evening field trips. Haze, smoke, and clouds make stargazing difficult. Too few of our schools own telescopic equipment, permitting in most cases only naked-eye observing.

One solution to the problem is for the teacher and his pupils to prepare a series of 2-by-2 slides of constellations, phases of the moon, comets, and so on. All the photographic equipment that is needed is a 35-mm. or Bantam camera, one or two floodlights, and a tripod.

Drawings are made with black India ink on white oak tag or drawing paper 11 by 14 inches. Drawings in India ink appear more realistic in the negatives than those made with crayon, pencil, or chalk.

When photographed, the negative will be in reverse, with the stars appearing white against the black background. The procedure for making the slides is:

1. Place the camera, without film in it, on a tripod and set the focus at the shortest distance — 2½ or three feet on most 35-mm. cameras. No special close-up attachment is necessary.
2. Set the camera for time exposure and press the shutter button. This will open the lens. Turn on the floodlights. For illumination, we used two 100-watt lamps in reflectors placed four feet from the drawings at a 45-degree angle to them.
3. Open the back of the camera and hold a piece of etched glass or waxed paper there. This will enable you to see the area that is to be photographed.
4. Place a drawing in this area, to check the proper focus. The drawing appears upside-down through the etched glass.
5. Lock the tripod in place. Make sure it does not move.
6. Trip the shutter to close the lens. Load the film into the camera.
7. Photograph the series of constellation drawings. It may be advisable to take and record a test series of shots at different shutter speeds and lens openings. Our experience has led us to use Super-XX film at an exposure of f/8 at 1/100 second or f/11 at 1/50 second.

After the film has been processed, the students are eager to bind the negatives in 2-by-2 slide binders covered with glass wafers to protect the film. They enjoy the slide-making project, and the results add interest to their study of astronomy and photography. They can "see the stars" during school hours, and their efforts contribute a valuable addition to the school's visual aids library.

HAROLD HAINFELD
Roosevelt School
Union City, N. J.

Sir:

In the February issue, page 97, Dr. Fritz Haber states, "Physicists . . . believe that a body has two different kinds of masses: the gravitational mass . . . and the inert mass. . . . A careful physicist always makes a distinction between these two attributes of a body, despite the fact that there is no experiment known which gives evidence that the two kinds are in any way different from each other."

These assertions could have passed muster 40 years ago, but nowadays even "a careful physicist" fails to distinguish between inertial and gravitational mass, for he believes with Einstein that the two are one and the same, not only in practice but in principle. It is precisely upon this basic identity that Einstein erected his general theory of relativity. From this identity springs the advance in Mercury's perihelion, the bending of starlight when it passes close to the sun, the reddening of light emitted by massive stars, and the expansion of the universe.

DAVID LAYZER
Harvard College Observatory
Cambridge 38, Mass.

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CONTENTS

COVER: Using a ladder instead of a spaceship, American Museum of Natural History artist Robert Kane goes to Mars, to put the finishing touches on one of the 14 new black-light murals at the Hayden Planetarium in New York City. When on exhibition, the murals are illuminated only by ultraviolet light. American Museum of Natural History photograph. (See page 175.)

BACK COVER: The planet Mars, photographed with the 200-inch Hale telescope. Three of the pictures are in blue light; the image in the lower right is in red light. Mount Wilson and Palomar Observatories photograph.

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Hayden Planetarium Black-light Murals

The large size of the new Hayden Planetarium murals is shown by this picture of Robert Kane touching up pait of the solar eclipse mural. Photographs on this page are by the American Museum of Natural History.

WITH THE HELP of such devices as fluorescent paint and "black" light, and the co-operation of artists, illustrators, electricians, carpenters, and tinsmiths, the Hayden Planetarium in New York City has recently installed a series of 14 murals, unique as astronomical displays. In the first floor corridors of the planetarium building, the murals cover an area of 4,000 square feet.

The process involved, in many cases, the projection of observatory photographs onto the wall surfaces, so that the paintings were actually "built" onto the walls. For Mars (see the front cover), a combination of astronomical descriptions, drawings, and some photographs was used. Each subject was first underpainted with flat white and tones of gray; then it was overglazed by the luminous paint to the desired color, the artist working under the ultraviolet light so that the true effect could be brought out. The luminous paint was a commercial product containing rock sulphides, fluorescent under ultraviolet light, a material that was originally used for theatrical costumes, but which is attaining ever-widening applications for exhibit purposes.

The experience of this specialized type of artistic work was described by Joseph M. Guerry, designer of the murals, as "like painting with fire." He said, "The black-light technique gives the illusion of deep space and a three-dimensional effect that makes some of the stars seem to go back a million miles. One is not conscious of the painted walls, and, instead, the planets appear to be hanging in space."

Thomas Voter, the American Museum of Natural History artist in charge of the murals group, pointed out that the airbrush method was frequently used to emphasize the luminous quality, particularly in such subjects as the aurora and the gaseous nebulae. He stated that the "old master" technique was followed, rather than the techniques of modern commercial work in which there is no attempt at modeling.

The 14 subjects of the murals are: sunspots, solar prominences, the aurora borealis, a total solar eclipse, Mars, the Whirlpool nebula (a galaxy in Canes Venatici, M51), Morehouse's comet, the Great Nebula in Andromeda, the Leonid meteor shower of November, 1833, Saturn and its rings, a lunar eclipse, a globular star cluster, the Horsehead nebula in Orion, and the Great Nebula in Orion.

To make even more realistic the mural of the aurora, a moving ultraviolet light, hidden from view, sweeps slowly over the wall to create the illusion of the shimmering blue-green curtains of the northern lights. The star field of the sky on a clear winter night shows literally hundreds of stars, with the tail of a comet seen in their midst, perforating the dark sky and appearing to twinkle brightly. The lunar eclipse is partial, with the rich coppery color of the earth's umbra depicted realistically; the effect of relief on the lunar mountains and craters is very pronounced.

Mr. Voter is wearing a nose mask while applying colors with an airbrush to the northern lights mural.

These astronomical murals were the first project to be completed under a new prefabrication system recently installed at the American Museum of Natural History by M. F. Harty, assistant director for exhibition and plant management. The entire operation was speeded up for the bulk of the work, as construction and painting of most of the murals and experimentation with lighting effects were carried out in the various museum shops. Finishing touches after the actual placing of the murals was all the work that took place in the planetarium. This installation required five weeks, but it was carried on without interruption of the regular lecture schedule of the planetarium. An unusual problem of timing had to be solved by an arrangement of alternating shifts, for the artist had to work under ultraviolet light to be sure he was achieving the desired effect, whereas the carpenters and electricians had to have ordinary white light.

The Hayden Planetarium is now in its 18th year of operation. It opened in October, 1935, under the direction of the late Dr. Clyde Fisher, who in 1927 was founder and first president of the Amateur Astronomers Association at the American Museum of Natural History. The present director is Robert R. Coles.

As part of its regular demonstration for April 16th through May 31st, the Hayden Planetarium dramatizes the formation of Meteor Crater in Arizona, and the audience is able to imagine itself situated on the floor of the crater.

A New Telescope in Scotland

By E. Finlay-Freundlich and Robert L. Waland
University of St. Andrews Observatory

THE INTRODUCTION of correcting plates by B. Schmidt in 1932 produced a revolution in astronomical optics. It met an urgent demand of astronomical research — the possibility of recording larger areas on the photographic plate than a Newtonian telescope is capable of picturing sufficiently well. The classic Schmidt telescope, consisting of one spherical mirror plus a correcting plate, satisfies this demand, but it suffers from various inconveniences. The focal surface lies inaccessible inside the telescope and is, in addition, spherical, which makes the use of curved plates necessary. In consequence, accessory instruments cannot easily be used in combination with classic Schmidts, nor is it possible to derive celestial co-ordinates of an observed object from the plates according to well-established astrographic methods.

When the new observatory of the University of St. Andrews, in St. Andrews, Scotland, was created in 1939, it was decided to start research after the end of the war on an improved type of Schmidt telescope, the Schmidt-Cassegrain, to consist of two spherical mirrors, the concave main mirror and opposite to it the convex secondary, plus a Schmidt plate, arranged in such a way that the focal plane surface falls behind the central hole of the main mirror at an easily accessible position. Dr. E. H. Linfoot, of Cambridge, worked out the theory of this new optical system, while R. L. Waland (whose detailed description of the making of the telescope follows) organized the optical and mechanical workshop. It was decided to make a half-scale pilot model first before embarking on the larger project of a 37-inch telescope.

The pilot model fulfilled all expectations. Over a field of five by five degrees, the stellar images are symmetrical and extremely sharp. The field is plane to such an extent that the photographic emulsion must be coated on plate glass, since the depth of the focus is less than the average deviation of a photographic plate from a plane surface. The field is free from optical distortion. The limiting magnitude of the 18-inch pilot model using a working aperture of 15 inches, after exposures of one hour, lies near the 17th magnitude.

IT WAS DECIDED that all constructional work for the telescope should be carried out in the observatory, which meant the equipping of a complete mechanical and optical workshop capable of dealing with the full-scale model. This was accomplished, in spite of postwar restrictions, in about two years. During this period an optical grinding machine was designed and constructed to surface disks up to 38 inches in diameter.

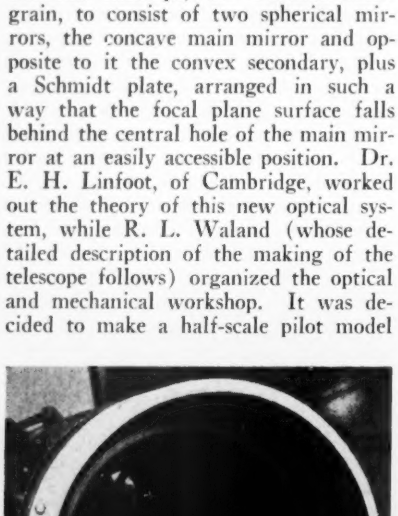
The pilot model was in operation in another two years — in the spring of 1950. The primary concave mirror is 18¾ inches in diameter with a central hole of 6.3 inches. The secondary convex mirror is 9.6 inches. Both are of Hysil glass by Chance Brothers, of Birmingham. The 21-inch Schmidt plate was made from Pilkington's white plate; this is a plate glass of optical purity developed by this firm during the latter war years. The focal surface is 6.5 inches outside the pole of the primary, flat and very accessible.

Due to the very high optical performance of these instruments, it was considered advisable to spare no effort in the mechanical work. The primary has a very complete flotation system. The movement of the mirror in its cell cannot be detected with the best gauges obtainable and is definitely less than 1/50,000 inch. The secondary is very carefully mounted in a cast-iron cell attached to a central tubular arbor, which is part of a bimetallic compensator to maintain constant distance between the two mirrors. Because of temperature lag complication, the compensator is made variable to suit the average observing conditions.

To reduce to a minimum the flexure of the spider carrying the secondary, a weight is placed at the other end of the arbor. The spider carrying the whole assembly is attached to the robustly constructed compensator. The spider has four arms, each having a diamond-shaped box section. This reduces the obstructional differences for on- and off-axis beams, thus rendering the instrument more suitable for photometry.

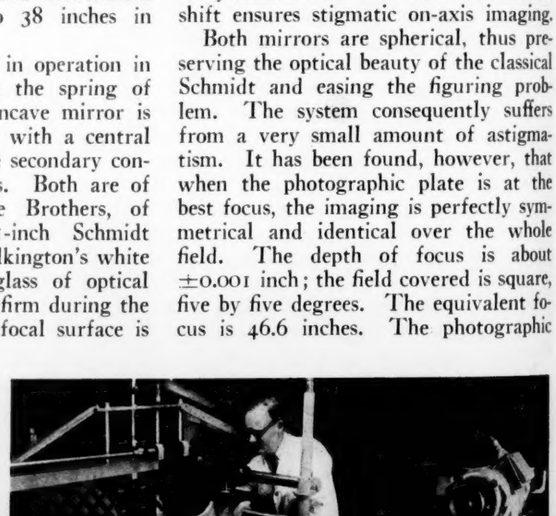
Provision for squaring on both mirrors is provided, as well as for axial and lateral shift of the Schmidt plate. The axial shift is essential to annul the primary coma of the mirrors. The lateral shift ensures stigmatic on-axis imaging.

Both mirrors are spherical, thus preserving the optical beauty of the classical Schmidt and easing the figuring problem. The system consequently suffers from a very small amount of astigmatism. It has been found, however, that when the photographic plate is at the best focus, the imaging is perfectly symmetrical and identical over the whole field. The depth of focus is about ± 0.001 inch; the field covered is square, five by five degrees. The equivalent focus is 46.6 inches. The photographic



Left: A view of the correcting-plate end of the pilot model. The wire above Mr. Waland's hand is part of the dew-prevention system. He is removing dust specks by means of a camel's-hair brush.

Right: The large mirror was polished with beeswax squares, on the spherical steel tool that had previously carried the bathroom tiles used for grinding. At the left rear is the specially built grinding and polishing machine.



aperture is 15 inches, the stop being placed midway between the primary and the Schmidt plate. The focal ratio is f/3 nominal (approximate) and f/3.9 effective (approximate) due to the central obstruction of the secondary. For special investigations the telescope can be used without the stop at the full aperture of 18 inches.

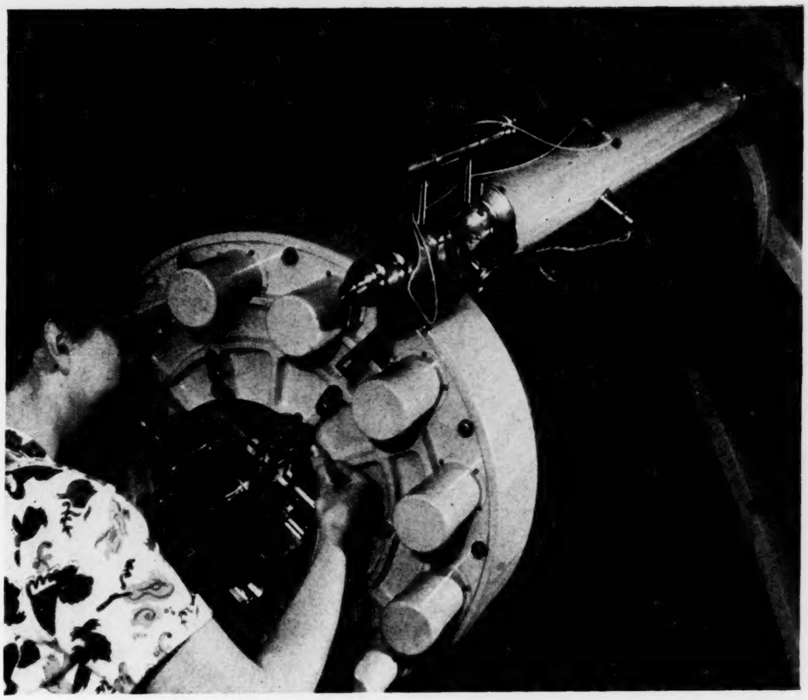
A microphotographic survey of the imaging of this instrument is being published by Dr. Linfoot and Dr. J. Cisar, of St. Andrews.

The Schmidt plate was ground and polished with a flexible lap and tested during fine grinding by the matched ball method against an optically ground plate with varying degrees of slope. The balls lie at the locus of equal distance in the air wedge between the plates along a precalculated curve;* residual errors of the surface are figured out during polishing with the complete system under optical test.

It must be emphasized that this telescope is purely an experimental model, although it is being used successfully for astronomical observations. Improvements in both general design and methods of manufacture have resulted from our experience in making and using the half-scale model.

A brief description of a few of the improvements incorporated in the full-scale instrument may be of interest. The complete cylindrical tube is double, for two reasons. The air gap between helps to shelter the mirrors from sudden temperature changes; and the outer tube carries the optics while the inner is floated and maintains very precise optical alignment with changing inclination. Two spiders, both of diamond cross-section, one inside the other, for photometric reasons, carry and define the axially and radially floated secondary mirror. The inner spider carries the mass of the 18¾-inch secondary and its flotation system while the outer defines its position both radially and axially.

The two spiders "breathe" during temperature changes since the outer locating spider is connected to the cell end of the tube by invar rods, while the



The refractor attached to the 18-inch pilot telescope is only a finder, for guiding is done with two eyepieces just off the edge of the square plateholder. The protruding cylinders are part of the primary mirror flotation system. Crown copyright reserved.

inner weight-bearing spider is connected to the outer weight-bearing tube of the telescope. Both the primary and secondary mirrors are located radially near their poles to insure that they remain co-axial during temperature changes. The secondary is floated radially at its center of gravity. A hole is removed from its center which serves the triple function of radial location, radial support, and partial axial support. Approximately one third of the axial weight is taken at this central hole, while the remaining two thirds is near the rim of the mirror, the back half being reduced in diameter and separated by a shoulder to which the axial flotation system is connected. Thus all mechanical work is hidden behind the mirror, and the obstruction is thereby reduced to the bare diameter of the secondary mirror.

It is obvious that a secondary mirror in any telescope does not enjoy the same rigidity as a primary because of the necessity of letting light through to the main mirror! By the use of the above method the outer locating spider is relieved of all weight other than its own. The flexures will consequently be of a second order.

The effect of spider flexure would be to introduce a slight slope in the field of best focus with accompanying slight changes in imaging. The slope amounts to a few seconds of arc for a change in inclination of 90 degrees in the half-scale model. Fortunately, by adjusting the secondary at the zenith, the instrument is usable through the usual inclinations of the tube met with in practice.

The Schmidt plate of the full-scale telescope is by Schott, of Jena, and is of ultraviolet transmitting glass, 38¼ inches in diameter and seven eighths of an inch thick. Provision has been made for incorporating at a later date an objective prism of the same glass.

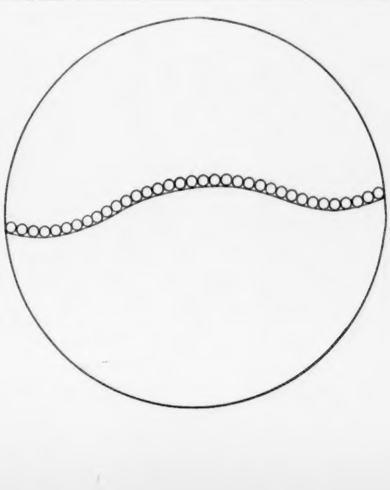
The 18¾-inch secondary mirror has been completed in the optical shop, and the 37-inch primary is nearing completion. The mechanical parts are also well under way.

The mounting of such an instrument is being given the most careful consideration; at the moment the favorite is a compensated fork type which reduces the fork tines to a little more than half the diameter of the tube.

*This method is described on page 352 of *Prism and Lens Making*, by F. Twyman, 1952 edition, published by Hilger and Watts, Ltd.:

"The surface is tested during the grinding process by removing it from the machine; placing upon it a flat surface inclined to it by a slight angle, this being made by resting the flat plate on three little blocks of glass of suitable thickness, and allowing steel balls such as those intended for ball bearings (selected to be of exactly the same diameter) to roll down between the two surfaces so that they lie in a curve which indicates the shape of the surface. . . ."

This method is E. H. Linfoot's variant of one originated by Roger Hayward; the accompanying diagram shows the steel balls outlining a curve on the correcting plate. — ED.



AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 88th meeting of the American Astronomical Society at Amherst, Mass., in December. Complete abstracts will appear in the Astronomical Journal.

Accelerations of Stars by Interstellar Clouds

The random velocities of stars are believed to be different for those of different ages, with young stars (types *O* and *A*) moving at about 10 kilometers per second with respect to each other, and older stars on the main sequence (*G* to *M*) moving at about 20 kilometers per second, on the average. Some years ago, Dr. Lyman Spitzer, Jr., of Princeton University Observatory, proposed that this correlation between age and velocity results from a gradual acceleration of the stars in encounters with interstellar clouds. But the work of Dr. Spitzer and Dr. Martin Schwarzschild at that time was inconclusive, chiefly because the approximations made were not very realistic.

Now a more accurate analysis has been carried through by Dr. Spitzer, considering the effect of galactic rotation on the relative motion of the interstellar clouds; this had previously been neglected. The results indicate that the mechanism will, in fact, accelerate stars from 10 to 20 kilometers a second in about a billion years, provided that large irregularities are present in the distribution of interstellar matter, and that the scale of such irregularities is about 1,000 light-years. Observations indicate that such irregularities are actually present in the Milky Way.

The agreement between theory and observation lends further support to the current belief that stars of all types are being formed continuously from interstellar matter.

Southern Hydrogen-Alpha Emission Regions

Since regions emitting radiation at the wave length of the hydrogen-alpha line have been found to be prime indicators of spiral structure in other galaxies, the spiral arms of our own galaxy can probably be traced best through these patches of emission nebulosity along the Milky Way. Following the discovery by Morgan, Sharpless, and Osterbrock of two sections of spiral arms in the northern Milky Way (see *Sky and Telescope,* April, 1952), observations to detect similar structure in the southern Milky Way were begun at the Boyden station of Harvard Observatory. Some results were presented by Dr. Bart J. Bok, Michiel J. Bester, and Campbell M. Wade.

The principal instrument used in the present survey is a camera fitted with a 3-inch Zeiss-Sonnar lens (f/1.5), on loan from Richard S. Perkin, employing a Corning 2403 red filter and a Baird interference filter which isolates the Hα line.

The section of the southern Milky Way investigated at the time of the report extended from the southern Coalsack, at galactic longitude 265°, to the Scutum cloud, at 355°. This section adjoins the Carina-Crux-Centaurus section, between 250° and 270°, for which an earlier survey had been made with the Armagh - Dunsink - Harvard telescope. The region from 180° to 250° is now being photographed at the Boyden station.

The emission features are very strong between longitudes 250° and 265°, but either very weak or absent from 265° to 300°, where there are at best some very weak patches that still require confirmation. Thus, the galaxy between 265° and 300° shows little evidence for spiral structure.

Hydrogen emission patches are strong and abundant between longitudes 300° and 345°, where the Harvard astronomers have found 16 certain emission regions and 10 additional probable regions. The emission regions follow very closely along the equator of the galaxy, and are not necessarily seen projected against the brightest parts of the visible band of the Milky Way. No emission regions are found more than four degrees from the galactic plane.

A list of associated *O* and *B* stars has been prepared, and these stars are now on the Boyden station spectral and photoelectric program for further study to determine their distances.

Part of a photograph made at the Boyden station of Harvard Observatory, with a 3-inch camera and filters isolating hydrogen - alpha light. The region shown includes the meeting point of Sagittarius, Serpens Cauda, and Scutum. The principal objects, from top to bottom, are NGC 6604, M16, M17, and the small Sagittarius cloud. The nearly right-angled dark area to the east (left) of the cloud contains IC 1284. New H-alpha emission regions are: about 1¼ inches from the top and ¾ inch from the right; more than 1½ inches from the top and ⅞ inch from the left. The exposure was six hours, unguided, on Eastman 103a-E emulsion, enlarged here five times. Harvard Observatory photograph.

Radiative Opacity of Stellar Material

The density of radiation in the interior of a star is very high, even compared with the large density of matter. The interaction of the radiation with the atoms of the stellar gas is important to our understanding of the internal structure of the star. This interaction, determined by the opacity, is necessary to compute the temperature, pressure, distribution of matter, and energy generation inside the star.

Previous calculations of the opacity have not properly accounted for the effect of the very high internal pressure in a star and the strong interaction between the particles of the gas. This effect has been shown to be quite important; it increases the degree of ionization and also affects the interaction of the electrons with radiation. Dr. Harold Zirin, of the Rand Corporation, has studied closely the motions of electrons about the ions of the stellar gas. As a

result, he has been able to estimate approximately the magnitude of the interaction effects and to compute more accurate opacity tables.

The stellar material appears to be more transparent than indicated by classical studies. One consequence of this fact is that the sun could have a considerable convective core.

Eccentric Binary

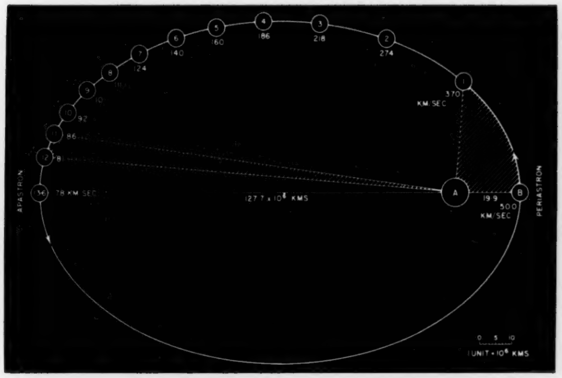
A detailed spectrographic study of a massive binary system, HD 37756, has been carried out by Dr. Joseph A. Pearce, director emeritus of the Dominion Astrophysical Observatory. This binary is composed of hot stars of spectral type *B1* revolving in orbits of eccentricity 0.73, extremely high for stars of this type. The period is 27.2 days and, as the accompanying orbit diagram shows, the velocity at periastron is about 500 kilometers per second, but at apastron it is only 78 kilometers per second.

For two days at periastron, the stars are separated by less than 20 million kilometers, whereas at apastron, 13.6 days later, their separation is about 128 million kilometers. Another diagram shows their orbits compared in size to that of Mercury. The peculiar shape of the radial-velocity curve results from the rapid changes in orbital velocity of one star with respect to the other.

A magnitude difference of 1.14 was derived from spectrophotometric measurements of the line intensities at wave lengths 4471 and 4340 angstroms, on eight spectrograms. Absolute magnitudes of −2.60 and −1.46 were found for the components from the measured equivalent width of the hydrogen-gamma line. The inclination of the orbit plane to the plane of the sky was estimated to be 52 degrees, on the basis of the mass-luminosity relationship. The masses are estimated to be 13.3 and 8.5 suns, respectively; the radius of the larger star is 5.8 times that of the sun, and of the smaller star 3.4 times the sun's.

The orbital elements were computed from 17 observations near the nodes, that is, at the times of maximum relative velocity of the component stars; these observations are represented by the open circles on the velocity curve. Blended spectra, shown by solid circles, were omitted from the solution. Yerkes observations of 1905-1907 are represented by the triangles.

HD 37756 is a 5th-magnitude star in the constellation of Orion, at a distance of 1,250 light-years.



The relative positions and velocities of the components of HD 37756 illustrate the working of Kepler's law of equal areas. Within the circles are marked the days after periastron passage. Outside of each circle is the velocity in kilometers per second. Dominion Astrophysical Observatory diagram.

Red Dwarf Models

No satisfactory model of a red dwarf star can be constructed under the assumption that radiative equilibrium holds throughout the star. The difficulty is that the computed central temperature comes out so high that the computed luminosity supplied by the proton-proton reaction is much higher than the observed brightness. It has been pointed out, however, by B. Stroemgren, that later-type dwarfs may be expected to have extensive hydrogen convection zones extending down into their interiors, as a result of their low temperatures and high densities. Thus, in the region in which convection transports energy, the temperature gradient is lower than in radiative equilibrium, and the central temperature may therefore be smaller than that computed under the assumption of radiative equilibrium throughout the star.

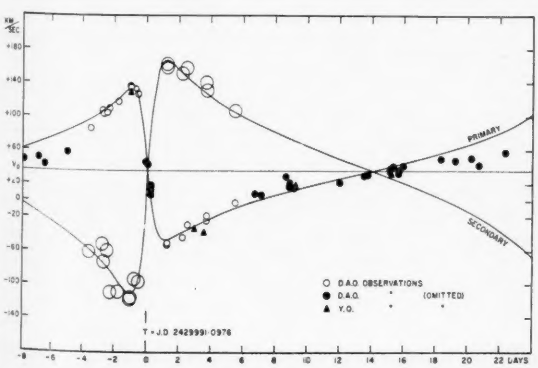
Dr. Donald E. Osterbrock, Princeton University Observatory, has computed a series of models, each corresponding to a different depth of the outer hydrogen convection zone. The atmospheric opacity, which is uncertain in nature for *M* dwarfs, was assumed to be caused by the negative hydrogen ion. Other assumptions had to be made, such as of an internal opacity due to metals in Russell-mixture proportions, and the models were applied to the double star Castor C (YY Geminorum), a red dwarf with a well-determined mass, radius, and luminosity.

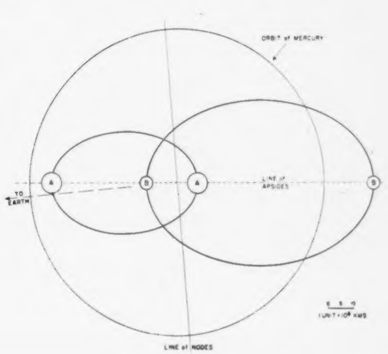
The hydrogen convection zone is computed to extend to a depth of about 35 per cent of the star's radius and to include about 12 per cent of its mass; the central temperature is about 8,600,000° absolute. With such a deep outer convection zone, large turbulent elements may be expected to appear near the surface of the star, giving rise to the erratic fluctuations in brightness observed in many *M* dwarfs, earning them the designation of "flare" stars.

Clustering by Expansion

Einstein's general theory of relativity has provided a simple interpretation of the two most fundamental features of the structure of the universe: the over-all uniform distribution of matter and the expanding of the metagalaxy. Einstein's theory exhibits the expansion as a purely gravitational phenomenon, a consequence of his law of gravitation and the postulate that there exists nowhere in space a preferred region or direction.

In describing a new cosmogonical hypothesis, Dr. David Layzer, of the Forrestal Research Center, Princeton University, pointed out that perhaps the next most striking feature is the clustering of matter in the small. Matter appears to have convened into more-or-less distinct self-gravitating systems within a hier-





Left: The radial-velocity observations of the spectroscopic binary HD 37756.

Right: The orbits of HD 37756 compared to the orbit of Mercury. The sun's position would coincide with that of the center of gravity of the binary, at the intersection of the line of nodes and the line of apsides. Dominion Astrophysical Observatory diagrams.

archy extending from the great clusters of galaxies to the planetary and planetary-satellite systems. It seems probable that during the very earliest stages of the expansion matter in gaseous form uniformly pervaded all of space. The interpretation of gravitational clustering therefore presents an evolutionary problem.

Dr. Layzer bases his description on the single postulate that the expansion of the universe requires a continuing supply of energy, which can be liberated only by the local clustering of matter. He drew the analogy of an ordinary three-dimensional expanding sphere on which gravitating particles are uniformly distributed. If it is required that no energy be transferred between the sphere itself and the particles on its surface, conservation of energy demands that local clustering occur, provided the initial kinetic energy of the particles is not too great and that the distribution of the particles remains uniform in the large.

In the universe itself, when an initially uniform distribution of particles began to expand, tiny condensations formed and liberated just enough energy to maintain the expansion. As the universe expanded still further, these condensations convened into small clusters, these in turn into larger clusters, and so on. Throughout, the large-scale distribution of matter remains uniform, but the expansion tends to generate a hierarchy of very loosely knit clusters within clusters.

Tidal interactions, however, tend to disrupt small clusters as they come together to form larger ones; thus, energy is continually being funneled from the clusters of every given level to the smaller clusters on the next lower level. The net rate of change of energy on any level can be positive or negative — at some levels thinning out takes place, but is matched by the formation of more compact clusters on others. For instance, we observe star clusters that are very young and yet disintegrating, but the globular clusters are both old and compact.

According to Dr. Layzer's theory, the small astronomical systems came into being earlier than large ones. The earth, for example, should be older than the galaxy. The galaxies themselves should tend to form clusters even while they are on the whole rushing away from each other as part of the expansion of the universe. The great cluster of galaxies in Virgo may one day be part of an even larger aggregation of clusters of galaxies. Three processes contribute to the shaping of metagalactic structure: clustering, funneling, gravitational contraction (and the consequent release of radiation).

Following a calculation published by Einstein in 1918 for the original static spherical universe, Dr. Layzer has calculated the energy of an expanding, homogeneous, spherical Einstein universe. If the distribution of matter were to remain uniform, the energy per unit rest mass would continually increase. The result represents the energy liberated by local clustering, and is apparently in accordance with the fact that such clustering is observed to exist. Ours appears to be a finite, spherical, positively curved universe, as postulated by Einstein. On the other hand, for flat and negatively curved universes (which are infinite), energy can be conserved without clustering.

With certain necessary assumptions, Dr. Layzer computes the present radius of curvature to be a million million parsecs, or about three trillion light-years. Before the expansion ceases, the radius will be a million times as great as this. The period of a complete expansion-contraction cycle comes out 10 million million million years. The mass of the universe is put at 10^{31} times the mass of the sun.

Perseid Statistics

The trails of 115 Perseid meteors, appearing on Harvard photographs from 1893 to 1952 in the period July 28th to August 24th, have been analyzed by Frances W. Wright and Dr. Fred L. Whipple, of Harvard Observatory.

The trails are from 23 meteors photographed simultaneously at two stations and 92 at one station only. Perseid activity attains its maximum on August 12th, with 62 per cent of the meteors appearing on the four days, August 10-13, inclusive.

The mean radiant of the stream moves eastward $43' \pm 2'$ per day and northward $7' \pm 2'$, with the right ascension $45° 56'.0$, declination $+57° 45'$ (corrected), when the sun is at longitude 139° (1950 co-ordinates). No significant deviation in the radiant or its motion appears to exist among photographic, radar, and visual observations, except that the scatter is probably greater for faint than for bright meteors. The photographic meteors appear to be relatively more numerous near maximum activity than the fainter radar Perseids observed at Manchester, England.

Eleven observed velocities from double-station Perseids give a mean velocity of 60 kilometers per second. The mean error of a single velocity is ± 0.7 kilometers per second, relatively great in comparison with slower meteors.

The average scatter of meteors' paths appears to increase linearly with the width of the stream of meteors in space. For seven photographic showers the correlation has been found to be excellent: The scatter increases from nearly zero stream width for the Draconids at a rate of 0.87 minute of arc per million miles of stream width. The fact that the Taurids (37 days "wide") and Geminids follow the scatter-duration relationship shown by such recognized cometary streams as the Draconids, Orionids, and Perseids, casts doubt on Hoffmeister's proposal that the Taurids and Geminids are "ecliptical currents," different in character from the cometary streams.

SSEC OUTMODED BY NEW CALCULATOR

In February, 1951, this magazine carried a story on the motions of the five outer planets. With the aid of the Selective Sequence Electronic Calculator of the International Business Machines Corporation, the paths of these planets had been traced from the year 1653 to 2060. Although it operated 1,000 times faster than a "perfect" human computer, who would have required more than 80 years for the planet task, the five-year-old SSEC has been dismantled because it is already out of date.

Its successor, the IBM Model 701 calculator, is 25 times faster and occupies only one fourth as much space as did the SSEC. Moreover, it does not have to be built in like the older machine, which constituted part of the building itself. The new calculator is already in production, its first dozen copies consigned to government agencies or defense industries. Time on the 701 will be rented at about $12,000 a month. The machine can average, in a typical problem, 14,000 arithmetic operations a second (or 16,000 additions or subtractions, or 2,000 multiplications or divisions a second).

MUSEUM AT GREENWICH

As the actively useful instruments of the Greenwich Observatory are being moved to Herstmonceux, the old building at Greenwich, England, is being converted into the National Maritime Museum. Most of the important older instruments will thus remain in an observatory originally established by Charles II in the interests of navigation. *Nature* lists among these Halley's transit instrument (the first in England), the zenith sector with which Bradley discovered the aberration of light and the nutation of the earth's axis, Airy's transit circle, erected in 1851 and by international agreement the instrument that defines the position of zero longitude.

The principal observatory building, designed by Sir Christopher Wren and erected in 1675, was damaged during the war, but has been restored as nearly as possible to its original appearance. The Octagon Room once occupied by the first Astronomer Royal, John Flamsteed, will be open to the public in May. A custom dating back to 1833, when a time ball was dropped at 1300 hours each day as the first public time-signal service in Great Britain, will be resumed.

NEWS NOTES

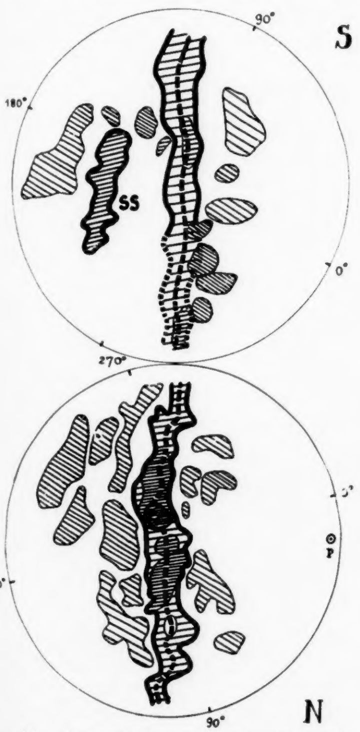
By Dorrit Hoffleit

A LOCAL SUPERGALAXY

The term "supergalaxy" does not designate an especially large or overluminous galaxy (it is unlike "supernova" in this respect), but refers to an assemblage of dynamically related galaxies. In the February issue of the *Astronomical Journal*, Gérard de Vaucouleurs, Commonwealth Observatory, Australia, describes the evidence for two such supergalaxies, in one of which our Milky Way galaxy is located. He proposes the existence of a "Milky Way" of galaxies that is flattened with its principal plane oriented at right angles to the plane of our system. It is probably some five million parsecs (five megaparsecs) in diameter and perhaps a megaparsec thick. We, that is, our own Milky Way, appear to be perhaps four fifths of the way out from the center, just as the sun is considerably off center in the galaxy.

Our position is inferred from the fact that many more galaxies are seen in one part of the supergalactic Milky Way than in the opposite direction. The center of this supergalaxy is more or less toward the Coma-Virgo cloud of galaxies; this direction is analogous to that of Sagittarius in the Milky Way system. Perhaps the Coma-Virgo cloud is the nucleus of the supergalaxy.

Dr. de Vaucouleurs points out that as early as 1923 the tendency of the large spirals to cluster along the galactic meridian of longitude 100° in both hemispheres had been noted by J. H. Reynolds, and that A. Reiz in 1941 found evidence for a metagalactic cloud extending several megaparsecs toward the region of the north galactic pole, confirming earlier results by E. Holmberg. More recently, Mrs. V. Cooper Rubin, of Cornell University, discovered a differential galactic rotation of the inner metagalaxy, with the pole of rotation at galactic longitude 14°, latitude +10°. Dr. de Vaucouleurs then investigated the spatial distribution of the galaxies in the Shapley-Ames catalogue of bright galaxies (Harvard *Annals 88*) and found a strong flattening of the system consistent with the assumption of a vast aggregation in rotation. In fact, the apparent pole of the geometric distribution, marked "P" in the accompanying diagram, at 15°, +5°, is close to that based on dynamical considerations.

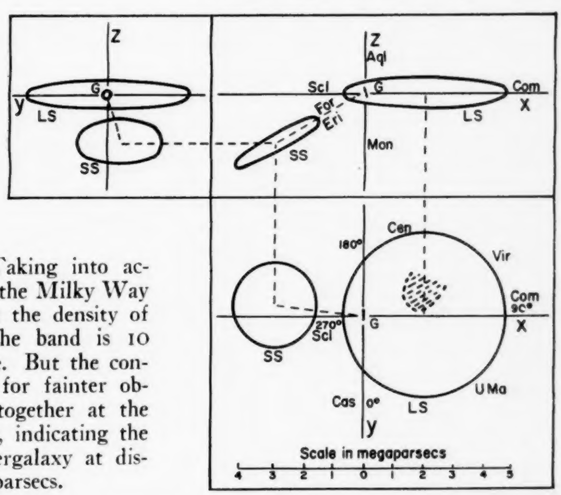


In this chart of the two galactic hemispheres (south at the top), the densest shading indicates where galaxies brighter than magnitude 13 are most numerous. Diagrams, courtesy the "Astronomical Journal."

Other such supergalaxies are known; for instance, there is a distant double supergalaxy in Hercules mentioned by H. Shapley in 1934. Ours, too, may be double, for the region marked "SS" in Dr. de Vaucouleurs' diagram appears to represent another system, about 2½ to three megaparsecs in diameter at perhaps three megaparsecs from the sun. It is located in the southern galactic hemisphere, extending from Cetus to Dorado through Fornax, Eridanus, and Horologium. Its thickness, estimated from its apparent dimensions in the sky (10 by 50 degrees) is about half a million parsecs. The second diagram from Dr. de Vaucouleurs' paper shows how the two systems may be related in space.

Excluding the SS system, the local "Milky Way" of galaxies includes in a band around the sky with an average width of 12 degrees two thirds of the total number of galaxies brighter than the 12th magnitude. Taking into account the obscuration of the Milky Way itself, this indicates that the density of bright galaxies inside the band is 10 times as great as outside. But the concentration becomes less for fainter objects, and disappears altogether at the 18th or 19th magnitude, indicating the ending of the local supergalaxy at distances of about six megaparsecs.

Right: A highly simplified plan of the space arrangement of the local supergalaxy (LS) and the southern supergalaxy (SS), drawn by G. de Vaucouleurs. The galaxy (G) is not to scale; the Coma-Virgo cluster is shaded.



IN THE CURRENT JOURNALS

ASTROPHYSICS AND INDUSTRY, by P. Swings, **Leaflet** No. 286, Astronomical Society of the Pacific, February, 1953. "Astronomers must keep themselves informed to some general extent on the main developments resulting from the work of the industrial physicists. It is in this way that they will be sure to take the fullest advantage of the admirable laboratories provided for them by the celestial objects. Similarly the industrial physicists would do well to visit astrophysical observatories from time to time."

THE ROCKET AND THE FUTURE OF ASTRONOMY, by Arthur C. Clarke, **Occasional Notes** of the Royal Astronomical Society, No. 14, December, 1952. "An attempt to summarize present achievements in the field of rocketry, as far as they are of interest to astronomers, and to assess what may reasonably be expected in the future on the basis of existing knowledge. Such an assessment seems all the more necessary in view of the many exaggerated or, alternatively, over-pessimistic statements that have appeared on the subject in the past few years."

TWILIGHT SKY COLOR

Much has been written on the interpretation of the blue color of the daylight sky, but the blue color of the sky overhead after sunset has been somewhat of a mystery. In the *Journal* of the Optical Society of America, February, 1953, the effect of the ozone layer of the atmosphere (assumed to lie between 20 and 35 kilometers altitude) on the sky color during twilight is discussed, on the basis of observations made at Sacramento Peak, N. M.

As the Rayleigh law of scattering predicts, during daytime when the sky is clear it is blue, but near sunset, were Rayleigh scattering alone operative, the zenith sky would become a grayish green-blue, and then yellowish in the twilight. It is, however, observed to remain blue throughout sunset and twilight.

On the basis that the total vertical

thickness of ozone is equivalent to 2.4 millimeters at conditions of standard temperature and pressure, Dr. E. O. Hulburt, of the Naval Research Laboratory, finds a strong effect of the absorption resulting from the Chappuis band of ozone, reducing some of the sun's rays in intensity and changing their yellow color to blue or blue-purple. At sunset, the zenith blue color is due about one third to Rayleigh scattering and two thirds to the ozone effect, and during twilight the color is entirely due to the ozone.

It has already been discovered by J. Dubois that the "shadow of the earth" which is seen opposite the sun during the early part of twilight is caused by the selective absorption of the Chappuis band of ozone.

FLEET NEW OBJECT

It is unusual news when a new object is reported moving faster than five degrees a day across the sky. Such a body was discovered on March 9th, in Ursa Major, by Dr. Albert G. Wilson on a plate taken with the 48-inch Schmidt telescope that is carrying on the sky survey at Palomar Mountain. Originally reported as of the 9th magnitude (subsequently magnitude 14 to 16 in March), at right ascension $11^h\ 14^m.7$, declination $+37°\ 12'.5$, the object was moving at an indicated daily rate of 17.2 minutes east, three degrees 16 minutes north. This is faster than the remarkable asteroid, Icarus, was moving at the time of its discovery with the same instrument by W. Baade in 1949 (*Sky and Telescope*, September, 1949, page 271). Such rapid motion suggests close proximity to the earth.

From observations made at Palomar and at Lick Observatory, Dr. Leland E. Cunningham, Leuschner Observatory, has computed the following orbit:

Time of perihelion	1953 Feb. 21.96 UT
Angle of perihelion	347°.166
Long. of ascending node	162°.847
Inclination of orbit	20°.340
Semimajor axis	2.43661 A.U.
Eccentricity	0.57689
Perihelion distance	1.031 A.U.
Aphelion distance	3.84 A.U.
Period of revolution	3.8 years

On the basis of this orbit, in which the period of revolution is still uncertain by several months, Dr. Cunningham computed an ephemeris for the interval from January 3 to June 12, 1953. The object, which is stellar in appearance and is probably an asteroid, reached a position closest to the earth on March 4th, when it was only 0.053 astronomical unit, less than five million miles, away from us. Its estimated magnitude then was 13.7. In May and June, it is expected to move from $14^h\ 41^m.0$, $+40°\ 31'$ on May 3rd to $14^h\ 49^m.2$, $+25°\ 02'$ on June 12th, and to decline in brightness probably from magnitude 19.5 to 21.1.

Amateur Astronomers

HARRY L. FREEMAN DIES

A longtime amateur astronomer and maker of telescopes and accessories, Harry L. Freeman, died in Los Angeles on February 27th at the age of 64. He was a past president of the Los Angeles Astronomical Society, and served as its secretary-treasurer for three years. At the time of his death he was a director of the Astronomical Society of the Pacific, and a member of the board of Western Amateur Astronomers.

A native of Detroit, Mich., Mr. Freeman attended the University of St. Louis. He was a captain in World War I, and in World War II served as a civilian automotive adviser overseas. He settled permanently in Los Angeles in 1936.

Always interested in scientific matters, he built his first telescope, a 7½-inch reflector, in 1931, and subsequently completed many others. He joined the Los Angeles Astronomical Society in 1939, devoting a great deal of time to the society's telescope making activities, and helping to develop the organization's membership.

CORNING ASTRONOMY CLUB

Organized in May, 1952, the Corning Astronomy Club has been meeting the first and third Wednesdays at the Corning Glass Center at 8 p.m. From the beginning of our group's history, we have followed a syllabus prepared by the writer, which has allowed us to progress in our studies in a consistent manner from some of the more elementary concepts through to studies of cosmology. Many movies and slides were shown, some of which were original, having been made by the scientists of the Corning Glass Works.

We are following a program of meteor observation, and we plan studies of the aurora by photoelectric means.

Visitors are welcome at our meetings.

WALTER R. REDMOND
119 E. 2nd St.
Corning, N. Y.

NEW YORK SPECIAL EVENT

On May 2-3, the New York Amateur Astronomers Association is sponsoring a special gathering for interested out-of-town amateur astronomers, many of whom have played host to AAA field trips in past years, and for its own members who are so situated that they cannot participate in the regular AAA activities.

The get-together will be at the American Museum of Natural History, and will open on Saturday, May 2nd, with registration from 10 o'clock until noon, followed by a luncheon. In the afternoon from 2:30 to 4:30 there will be museum tours, and trips to local places of scientific interest in the evening. A general meeting at 10 o'clock Sunday morning will include group discussions, and a special private showing will be given at the Hayden Planetarium at noon.

Further information may be had from Miss Aileen Pindar, chairman of the special events committee, at the Amateur Astronomers Association, Inc., American Museum of Natural History, New York 24, N. Y.

THIS MONTH'S MEETINGS

Buffalo, N. Y.: Buffalo Astronomical Association, 8 p.m., Buffalo Museum of Science. May 6, election of officers. Dr. F. Shirley Jones, Buffalo Museum of Science, "How Far to the Stars?"

Cambridge, Mass.: Bond Astronomical Club, 8 p.m., Harvard Observatory. May 7, annual meeting for election of officers; reports by members.

Amateur Telescope Makers of Boston. May 9, joint annual picnic with Bond Astronomical Club at Agassiz station of Harvard Observatory, Harvard, Mass.; picnic supper 5-6 p.m., talk by Dr. Bart J. Bok, "The Agassiz Station."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. May 15, Dr. R. S. Shankland, Case Institute of Technology, "Michelson and the Relativity Theory."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Dallas Power and Light Co. auditorium. May 25, John W. Marlow, "Kepler's Law and Constellations."

Indianapolis, Ind.: Indiana Astronomical Society, 2:15 p.m., Central Library. May 3, 20th anniversary meeting, panel of experts, "Astronomical Information Please."

Kalamazoo, Mich.: Kalamazoo Amateur Astronomical Association, 8 p.m., home of Mr. and Mrs. Hans Baldauf, 1307 Warren Pl. May 9, William Persons, "The Aurora Borealis."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. May 20, annual meeting, reports of officers and committees; elections.

Rutherford, N. J.: Astronomical Society of Rutherford, 8 p.m., YMCA. May 3, "Summer Constellations." Outdoor observing.

Sacramento, Calif.: Sacramento Valley Astronomical Society, public meeting, 8 p.m., Little Theatre, Sacramento Junior College. May 5, Dr. Otto Struve, University of California, subject to be announced.

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Building auditorium. May 2, Paul S. Watson, Maryland Academy of Sciences, "Building an Observatory."

INDIANA PUBLIC NIGHTS

On May 17th and 24th, the Goethe Link Observatory, Brooklyn, Ind., will hold public nights. Lectures will be given at 7:30 and 8:30, with the zodiacal light and the solar system, respectively, as the subjects for the two evenings. For a ticket (specify date and time), a self-addressed stamped envelope should be sent to the Astronomy Dept., Indiana University, Bloomington, Ind.

SOUTHEAST REGIONAL CONVENTION

The annual convention of the Southeast region of the Astronomical League will be held in Chattanooga, Tenn., Friday evening, May 15th, through Saturday, May 16th. The program will include talks and exhibits by members, and Dr. J. A. Hynek, Ohio State University astronomer, will deliver the principal address. There will be exhibits of instruments, apparatus, scrapbooks, and photographs.

On Saturday morning, an excursion will take place to Lookout Mountain, Chickamauga Dam, a part of the famous Tennessee Valley Authority system, the Chickamauga battlefields, and other points of interest in the vicinity.

Interested amateur astronomers everywhere and in the Southeast region particularly are invited to attend this convention. For information write to the undersigned, correspondent for the host group, the Barnard Astronomical Society.

ARTHUR H. JONES
P. O. Box 948
Chattanooga, Tenn.

MID-STATES REGION TO MEET IN OKLAHOMA

SAILBOAT BRIDGE, Oklahoma, is the location chosen for the annual convention of the Mid-States region of the Astronomical League, which will take place on June 12-14. Arrangements will be made by the Wichita Astronomical Society and the Tulsa Astronomical Society, with the latter responsible for program and advance publicity.

Dr. Balfour S. Whitney, professor of astronomy at the University of Oklahoma, will give the principal address, on the evening of June 13th, speaking about "Small Observatories."

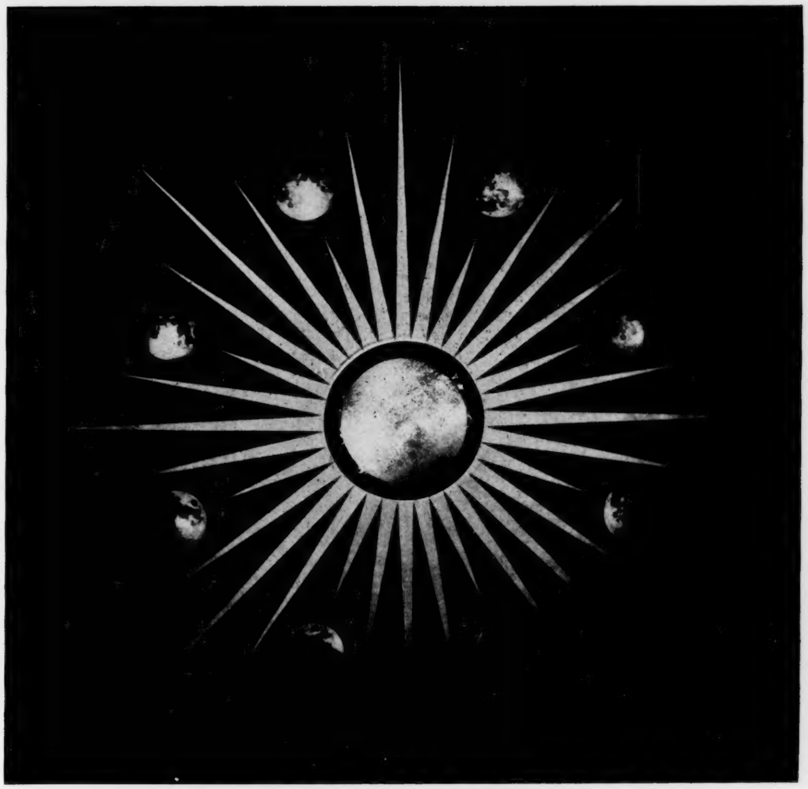
The convention will be held at the lodge and cabin area of the undersigned, located on highways 25 and 59 in the Lakes of the Cherokees. Activities will include paper sessions, displays, a star party and a chuckwagon barbecue (Saturday evening). Delegates are urged to bring portable telescopes and accessories for the star party. The registration fee is $1.00; the barbecue will cost $2.00 per person. All other meals will be the responsibility of the individual, as well as housing accommodations, which may easily be secured locally.

Additional information may be obtained from Robert Frossard, secretary, Tulsa Astronomical Society, 4218 East 25th St., Tulsa, Okla.

S. S. WHITEHEAD
2322 E. Douglas
Wichita, Kans.

SOUTHWEST CONVENTION

The Southwest region of the Astronomical League will hold its annual convention in Ft. Worth on June 19-20 at Texas Christian University, with the Ft. Worth Astronomical Society as host. A. W. Mount has been appointed convention manager, and Dr. Herman C. Sehested is program chairman. E. M. Brewer, of 5218 Morningside Ave., Dallas 6, Tex., is chairman of the Southwest region.



Transparencies on the ceiling of the Elihu Root auditorium of the Carnegie Institution of Washington, where the general convention of the Astronomical League will be held in September. The four-foot sun is a spectroheliogram, and the moon images are two feet in diameter.

WASHINGTON LEAGUE CONVENTION

Charles H. LeRoy, of the Amateur Astronomers Association of Pittsburgh, and past president of the Astronomical League, has been appointed program chairman for the general convention to be held in Washington, D. C., over the Labor Day weekend, September 4th to 7th.

The program will be divided into several categories: observing, including planets, moon, variable stars, aurorae; instrumentation; radio astronomy; junior activities. Amateurs are invited to prepare papers on any phase of these subjects, and should submit paper titles and short outlines (50 to 100 words) to Mr. LeRoy, at R. D. 11, Pittsburgh 15, Pa., not later than May 15th.

The National Capital Astronomers will be the host society. The Carnegie Institution is an ideal location for a convention. Its auditorium, where the sessions will be held, features transparencies of the sun and moon in the ceiling, made from actual Mount Wilson photographs, and murals on either side wall symbolize the research workers of the institution, depicting heroic figures representing astronomers, geographers, and explorers.

Exhibits will be displayed in the rotunda of the institution. Amateurs who plan to exhibit should write to Miss Mabel Sterns, 2517 K St., N. W., Washington 7, D. C.

Registration is open now; a registration fee of $1.00 should be sent to Mrs. Ione Alston, 20 Plattsburg Court, N. W., Washington 16, D. C. She will also handle reservations, at the Cairo Hotel only. Further details on reservations and on the convention plans may be found in the January and March issues of **Sky and Telescope,** pages 70 and 126.

WESTERN AMATEURS TO MEET

The fifth annual convention of Western Amateur Astronomers will be held in Los Angeles, Calif., August 14-16, with the Los Angeles Astronomical Society as host to the gathering. The sessions will convene on the campus of the University of California at Los Angeles in the Westwood section. Chalmers Myers is chairman of the convention committee. All communications concerning the 1953 WAA convention should be addressed to the convention secretary, Mrs. George Carroll, 7114 Summitrose St., Tujunga, Calif.

CLEVELAND PUBLIC NIGHTS

On May 21st and 22nd, the Warner and Swasey Observatory, East Cleveland, Ohio, will hold public nights. The observatory opens at 7:45 p.m., and the lecture is given at 8 p.m., on the subject, "Stars That Vary in Brightness." Observations through the telescope will take place after the lecture, weather permitting. Reservations for these public nights, last of the 1952-1953 season, may be made by calling the Case Institute of Technology, TYler 1-1000.

THE CLASSIFICATION OF STELLAR SPECTRA

By Otto Struve, *Leuschner Observatory, University of California*

"CLASSIFICATION is one method, probably the simplest method, of discovering order in the world." So wrote Abraham Wolf, onetime professor of logic and scientific method at the University of London, in the *Encyclopedia Britannica.* "By noting similarities between numerous distinct individuals as forming one class or kind, the many are in a sense reduced to one, and to that extent simplicity and order are introduced into the bewildering multiplicity of nature."

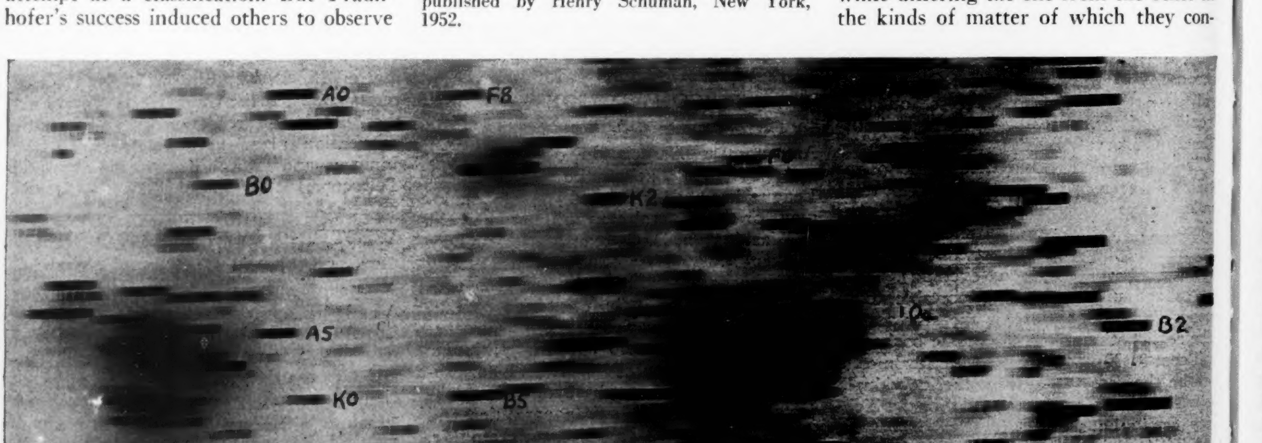
In astronomy the method of classification finds many uses, but ordinarily we think of it as referring to the study of the spectra of the stars. In 1815 Joseph Fraunhofer started his celebrated series of investigations of the spectra of the sun and the stars. He found that some of the brightest stars, for instance, Pollux, Capella, Procyon, and a few others, have spectra resembling that of the sun, while in the light of Sirius and Castor he saw only three wide, dark lines, two in the blue and one in the green region of the spectrum.*

These early beginnings of stellar spectroscopy were not sufficient to justify an attempt at a classification. But Fraunhofer's success induced others to observe more stars with the help of objective prisms placed in front of the telescope lens, or by means of small, direct-vision prisms at the eyepiece. In Italy, G. B. Donati described the spectra of 15 stars, while in America, L. M. Rutherfurd made a first attempt to classify the spectra of the brightest stars. Still later, L. Respighi observed the spectra of the stars from the roof of the Campidoglio in Rome (the same building in which the 1952 general assembly of the International Astronomical Union was opened), and Father Angelo Secchi, also in Rome, concluded that while "the stars are exceedingly numerous, their spectra can be reduced to a few well-defined and distinct forms which, for the sake of brevity, we shall call types." Secchi's work extended over several years and included the spectra of almost 4,000 stars — a truly remarkable result when we remember that he did not employ photograph! Today, even a fairly experienced observer would have difficulty in seeing more than three or four hydrogen lines in the light of Castor and Sirius, if he were limited to the use of a direct-vision spectroscope at the eye end of even a moderately large refractor.

Secchi's classification, with its four types, dominated astrophysics for nearly 50 years. It is of interest that his purpose was "to see if the composition of the stars is as varied as the stars are innumerable."

From the phenomenological point of view, it is interesting to note that in the beginning most classifications were designed simply for the purpose of bringing order into a mass of observational data. But as a field of science advances, the classifier is often prompted by his interest in a particular problem. We see that in stellar spectroscopy Secchi was already trying to study the abundances of the chemical elements in the universe, and this purely astrophysical problem has influenced the point of view of many classifiers of stellar spectra. Leading among them was, first, Sir William Huggins at Tulse Hill, near London, who in 1863 concluded that "the stars, while differing the one from the other in the kinds of matter of which they con-

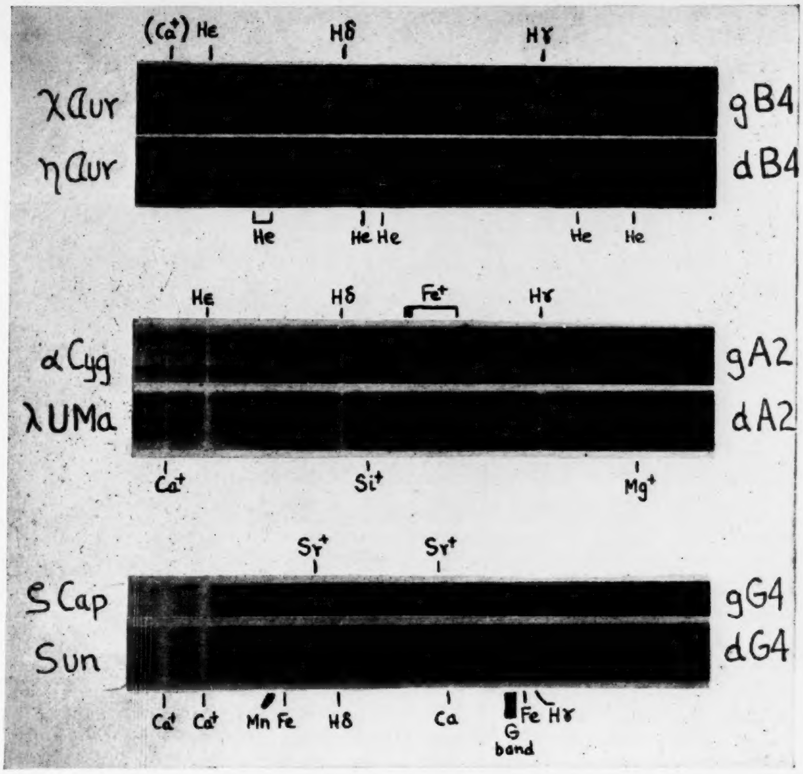
*For a more complete description of the history of spectral classifications the reader is referred to Giorgio Abetti's *The History of Astronomy*, translated from the Italian by the author's daughter-in-law, Betty Burr Abetti, published by Henry Schuman, New York, 1952.



This objective-prism plate of the region around Eta Carinae was taken 60 years ago, at Arequipa, Peru, with an 8-inch telescope, yet it still furnishes a good example of the method and basis of the Harvard system of spectral classification. Harvard Observatory photograph.

sist, are all constructed upon the same plan as our sun, and are composed of matter identical at least in part with the materials of our system." Next came Sir Norman Lockyer, also in England, who used the classification of stellar spectra which he and his collaborators had perfected to lay the foundation of our present theory of ionization. In effect, he related the various types of stellar spectra to various conditions in a laboratory light source, such as those of the electric arc or the spark.

The next great advance in spectral classification is associated with the name of H. C. Vogel, at Potsdam. Although Huggins had already successfully used photography for recording the spectra of the stars, the new process was applied by Vogel toward the measurement of the Doppler shifts of stellar absorption lines, and hence of stellar motions in the line of sight. It seems reasonable to believe that Vogel's spectral classification, which represents an extension of Secchi's four principal classes, was primarily intended to form a basis for the study of the motions of the stars. This was an entirely new viewpoint — one that was later to form the background of the work of W. W. Campbell at Lick and E. B. Frost at Yerkes. Although these American astrophysicists made no great effort toward the improvement of the existing classifications of stellar spectra, their interest in radial velocities undoubtedly led them to exert influence in directions that would enable them to study the average motions of different types of stars.



Examples of the differences between the spectra of giant and dwarf stars are shown in these typical spectra prepared by W. W. Morgan, of Yerkes Observatory. The upper spectrum of each pair is that of the giant star. Note the sharpness of the hydrogen lines for the early-type stars; the giant Zeta Capricorni has strong lines of ionized strontium, compared to our sun, which is a yellow dwarf star. The line in Chi Aurigae marked for ionized calcium is caused by interstellar calcium; its strength indicates the great distance of this star compared with Eta Aurigae. Yerkes Observatory photograph.

It is more difficult to discover the leading motive of the great work done at Harvard on spectral classification, embodied in the *Henry Draper Catalogue*. G. Abetti suggests that "the rapid progress in the manufacture of photographic plates and of instruments with wide field photographic objectives gave E. C. Pickering the idea of assembling a vast collection of photographs, extended over a period of time, so as to constitute as complete a history of the sky as possible. In addition to direct photographs, in order to catalogue the stars and obtain their magnitudes, the spectra were photographed with the objective prism."

This would suggest that the successive Harvard classifications, executed first under the direction of Pickering and later under H. Shapley, by Mrs. W. P. Fleming, Miss A. C. Maury, and especially Miss A. J. Cannon, who was aided and succeeded by Mrs. M. W. Mayall, represent the first of the classifications intended primarily as aids in the exploration of galactic structure.

The Harvard classification is the greatest single work in the entire field of stellar spectroscopy. With single-minded purpose, Miss Cannon classified the spectra of more than a quarter of a million stars, photographed with instruments that were modest in size and optical performance even when her work was started. To appreciate the full value of the *Draper Catalogue* I can do no better than quote from a 1935 paper by three of the leading astrophysicists of our time, H. N. Russell, C. H. Payne-Gaposchkin, and D. H. Menzel:

"The Harvard system is the product of the experience of a group, headed by Pickering and Miss Cannon, who have looked at a greater number of different stellar spectra than any other group; from this standpoint alone it must be recognized as having a maximum representativeness. . . . Multifarious as these criteria [of placing the spectra in convenient pigeonholes] are, they express the most *conspicuous* features from type to type. It is doubtful whether more outstanding bases for classification could be selected."

After a lapse of almost 50 years, every astrophysicist still relies heavily upon the *Draper Catalogue,* upon its more recent Harvard extensions, and upon several other catalogues built on the Harvard system of classification, such as the Bergedorf and Potsdam volumes, or the lists of stellar spectra from Upsala, Saltsjöbaden, and so on.

In the light of the success which the Harvard classification still enjoys today, we must recognize the wisdom of the two directors of the Harvard Observatory who withstood the temptation of embarking upon new, and in some respects more exciting astronomical ventures, and held tight to the original aim of giving us "as complete a history of the sky as possible." No other institution was prepared to carry out this vast program of routine classification — a project whose character is typical of astronomy and is unknown in the other physical sciences.

When the *Draper Catalogue* was being created, astronomers were not yet aware of the tremendous differences in the luminosities of stars that have the same Draper classes. Thus, a very cool red dwarf classified at Harvard as *M2* may be 50 million times less luminous than a supergiant of class *M2*. Hence, if we wish to use the *M2* stars as beacons of known luminosity to gauge from their apparent brightnesses their distances, and hence their relation to the structure of the Milky Way, we could easily make a tremendous mistake.

It was recognized early in the Har-

Effective Temperatures of the Stars

Type	T_e
B0	25,000°K
B1	22,500
B2	20,300
B3	18,000
B5	15,600
B6.5	14,000
B8	12,800
B9	11,800
A0	11,000
A1	10,300
A2	9700
A3	9100
A5	8700
A7	8100
F0	7600
F2	7000

	Main sequence V	Subgiants IV	Giants		Supergiants	
			III	II	Ib	Ia
F5	6600	6540	6470	6340	6200	
F6	6390	6210	6020	5910	5800	
F8	6150	5890	5620	5460	5300	
G0	6000	5750	5300	5150	5000	
G2	5730	5350	4990	4770	4600	
G5	5520	5080	4650	4470	4290	
G8	5320	4870	4440	4220	4000	
K0	5120	4650	4200	4010	3820	
K1	4920	4450	4000	3850	3700	
K2	4760	4280	3810	3700	3590	
K3	4610	....	3660	3540	3430	
K5	4400	....	3550	3430	3320	
K6	4000					
M0	3600	....	3340	3270	3210	
M1	3400:	....	3200	3150	3100	
M2	3200:	....	3090	3070:	3050:	
M3	....	....	2980			
M4	....	....	2850			
M5	....	....	2710			
M6	....	....	2600:			

Visual Absolute Magnitudes of the Luminosity Classes

Type	Main sequence V	Subgiants IV	Giants		Supergiants	
			III	II	Ib	Ia
B0	−3.9	−4.2	−4.5	−5.2	−6.0	−6.7
B1	−3.2	−3.8	−4.3	−5.1	−6.0	−7.0
B2	−2.6	−3.3	−4.1	−5.0	−5.7	−7.0
B3	−2.0	−2.8	−3.7	−4.5	−5.7	−7.0
B5	−1.3	−2.2	−3.2	−4.5	−5.7	−7.0
B6.5	−1.0	−2.0	−3.1	−4.3	−5.6	−7.0
B8	−0.5	−1.7	−3.0	−4.3	−5.5	−7.0
B9	0.0	−1.0	−2.0	−3.8	−5.5	−7.0
A0	+0.3	−0.4:	−1.1	−3.0:	−4.8	−7.0
A2	1.2	+0.2:	−0.7	−2.7:	−4.7	−7.0
A3	1.8	1.0:	−0.3	−2.5:	−4.6	−7.0
A5	2.2	1.4:	0.0	−2	−4.5	−7.0
A7	2.6	1.7:	+0.3	−2	−4.5	−7.0
F0	3.0	2.0:	0.6	−2	−4.5	−7.0
F2	3.2	2.5	0.8	−2	−4.5	−7.0
F5	3.5	2.7	1.0	−2	−4.5	−7.0
F6	3.8	2.9	1.0	−2	−4.5	−7.0
F8	4.1	3.1	1.0	−2	−4.5	−7.0
G0	4.4	3.2	0.7	−2	−4.5	−7.0
G2	4.7	3.3	0.4	−2	−4.5	−7.0
G5	5.1	3.4	0.2	−2.0	−4.5	−7.0
G8	5.6	3.4	0.4	−2.1	−4.5	−7.0
K0	6.0	+3.4	+0.2	−2.1	−4.5	−7.0
K2	6.4	......	0.0	−2.2	−4.5	−7.0
K3	6.9	......	−0.1	−2.3	−4.5	−7.0
K5	7.8	......	−0.3	−2.4	−4.5	−7.0
M0	9.2	......	−0.4	−2.4	−4.5	−7.0
M1	9.7	......	−0.4	−2.4	−4.5	−7.0
M2	10.1	......	−0.4	−2.4	−4.5	−7.0
M3	10.6	......	−0.5	−2.4:		
M4	11.3	......	−0.5			
M5	12.3					
M6	+13.4					

These tables concerning the Yerkes classification and the one on the opposite page are reproduced by permission from "Astrophysics," edited by J. A. Hynek. Copyright, 1951, McGraw-Hill Book Company, Inc.

vard work that spectral classes *O, B, A, F, G, K, M, R-N-S* represent a temperature classification, although the criteria were developed without any preconceived physical ideas. A second dimension in classification had already been introduced by Miss Maury, and it also occurs in the classification of Lockyer. But its importance was first clearly recognized by E. Hertzsprung, who showed that those stars which Miss Maury found to have exceptionally sharp and deep absorption lines (her criterion "c") are more luminous than the rest. In 1913, W. S. Adams invented the method of spectroscopic luminosities by relating the intensity ratios of certain lines to the intrinsic luminosities of the stars. This gave a new impetus to the problem of spectral classification — and its culmination is now found in the Yerkes system of W. W. Morgan, P. C. Keenan, E. Kellman, Nancy Roman, W. P. Bidelman, and their numerous collaborators.

It must be clearly understood that the leading motive of the Yerkes system is its usefulness in studies of galactic structure. The success it has achieved in this direction was demonstrated in a most dramatic manner when Morgan announced, at the Cleveland meeting of the American Astronomical Society in December, 1952, the discovery of two, and possibly three, spiral arms of the Milky Way in the vicinity of the sun (*Sky and Telescope*, April, 1952).

Morgan's criteria are entirely empirical. But he set out, from the start, to build up a two-dimensional classification. The stars were thus arranged, not in a linear sequence but in a rectangular pattern of pigeonholes, like the mailboxes at a post office. He used designations to represent the stars as dwarfs, giants, and so forth, on the second coordinate, as follows:

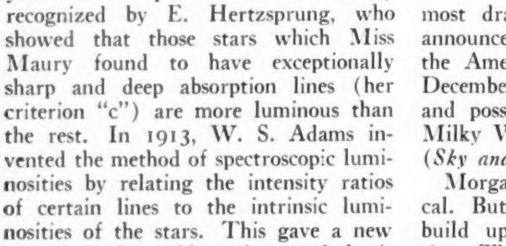
Ia...Most luminous supergiants
Ib...Less luminous supergiants
II...Bright giants
III Normal giants
IV Subgiants
V...Main sequence

We do not know yet *exactly* how the two dimensions are related to the temperature and luminosity of a star. To give us a rough guide, Morgan and Keenan have published two tables in the McGraw-Hill volume, *Astrophysics* (edited by J. A. Hynek, 1951), and these are reproduced here. Several examples of the Yerkes classification are shown in the illustrations. The vast majority of the stars fit into this two-dimensional scheme, but, as the table on page 187 shows, there are several groups that do not do so.

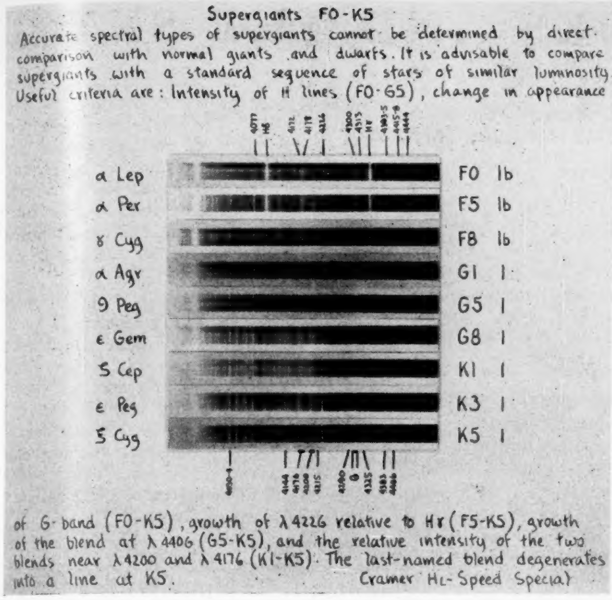
What are the principal values of the Yerkes classification? I believe them to be as follows:

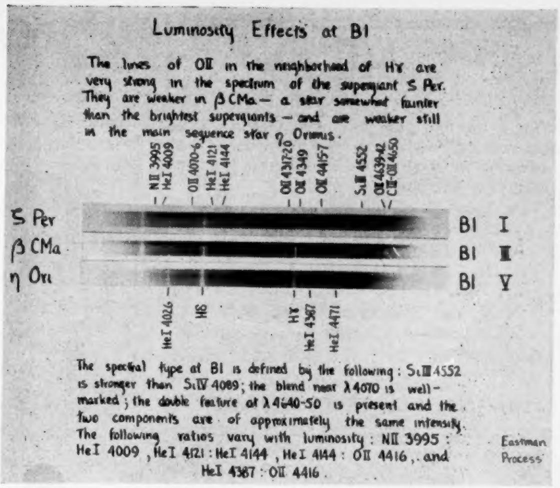
1. It is general, that is, it is not limited to a few regions of the Hertzsprung-Russell diagram.

2. It represents a gradual process of



The contrasting behavior of ionized barium at 4554 angstroms is shown here for classes K and A. In the supergiant Epsilon Pegasi, the line is stronger than in the giant Beta Ophiuchi. At class A, on the other hand, the line is absent in the supergiant Alpha Cygni, but well marked in the dwarf Mu Orionis. Spectra by W. W. Morgan.





These typical pages from "An Atlas of Stellar Spectra, with an Outline of Spectral Classification," by Morgan, Keenan, and Kellman, are reproduced (about half original size) by permission of the University of Chicago Press.

refinement over many years, and it is based upon uniform material obtained with the same instrument and similar photographic emulsions.

3. It is purely empirical in its criteria, yet its purpose was to locate, as precisely as possible, each star within the H-R diagram — from the absorption and emission features of its spectrum alone.

4. It has been applied to all the brighter stars (but to not nearly the numbers that are in the Draper catalogues), and therefore gives us a statistically significant sample of the Milky Way.

5. It used spectra of small dispersion (125 angstroms per millimeter at hydrogen-gamma) and therefore avoided difficulties arising from rotational and turbulence effects of line broadening.

6. It is limited, in its essential features, to stars of Population I (young stars, according to W. Baade) and does not attempt to compromise the differences that are known to exist between the spectra of stars of Populations I and II.

Have we heard the last word in the field of spectral classification? The answer is probably no. In the first place, we must recognize again that the main purpose of the Yerkes system was to aid in probing the Milky Way by establishing reliable criteria of stellar spectroscopic distances. More or less as a by-product this same system is the best we now have for following Secchi's original quest "to see if the composition of the stars is as varied as the stars are innumerable."

The fact is that astrophysicists of Secchi's kind have not yet produced a classification that would be especially adapted to their purpose. There have been a few isolated efforts. For instance, in 1933 I tried to refine the astrophysical classification of the hottest stars; this effort has suddenly proved its value in a recent study of Beta Canis Majoris pulsating stars by D. McNamara. Keenan has similarly improved the classification of the carbon stars.

It has been argued (by Russell, Mrs. Gaposchkin, and Menzel) that "if ever we develop a theory sufficiently exact and elastic to account for all of the features of stellar spectra, classification will be either unnecessary or will evolve into a shorthand listing of the parameters necessary to define the exact solution of the problem." But this ultimate aim is approachable by astrophysicists only asymptotically — and classifications are intended to aid in this approach.

It seems probable that future astrophysical adaptations of the Yerkes classification will make use of high spectroscopic dispersion rather than of low dispersion. Also, an effort will probably be made to arrange the stars within Population I according to a single criterion, such as the intensity of iron, which can be done only for a limited range in temperature. This will avoid the slightly conflicting criteria which are now used to give the best possible compromise for placing a star in its pigeonhole. Then, undoubtedly, an effort will have to be made to evolve an independent classification of the old stars of Population II, with small dispersion, in order that we may avoid the dangerous procedure of classifying an old star within a scheme that has been evolved for young stars.

Stellar Spectra Which Do Not Fit the Yerkes Classification

Group No.	Name of group	Approximate types	Spectral characteristics	Typical stars	Possible causes of differences
1	The two sequences of Wolf-Rayet stars: (1) Carbon sequence (2) Nitrogen sequence	WC5–WC8 WN5–WN8	Broad emission lines of carbon or nitrogen, respectively	HD 192103 HD 192163	Relative abundance of carbon and nitrogen
2	Early-type emission-line stars	Be–Ae	Emission lines of hydrogen	105 *Tau* κ *Dra*	Extended gaseous envelope around star
3	Stars with wide, shallow absorption lines	A–F	All lines having shallow, broad profiles	η *UMa* α *Aql*	Rapid axial rotation
4	Peculiar A-type stars; *e.g.*, Eu stars, Mn stars, etc.	A	Abnormal and variable intensity of lines of one or more of the ions: *Mn* II, *Si* II, *Eu* II, *Cr* II, *Sr* II	α *And* τ⁹ *Eri*	Intensification of certain lines by Zeeman effect of the star's magnetic field
5	Metallic-line stars	A–F	K line of *Ca* II abnormally weak compared with metallic lines	τ *UMa* 63 *Tau*	
6	Stars of population II (high-velocity stars, cluster variables, etc.)	F–M	Weakening of *CN* bands compared with normal G and K stars	δ *Lep* 31 *Aql*	Relative abundance of *C* and *H* probably involved
		R	Great strengthening of *CH* bands		
7	Carbon stars	C or R, N	Strong absorption bands of C_2 and *CN*. Abundance of *TiO*	*U Hya* *UX Dra*	Abundance of carbon
8	S-type stars	S	Absorption bands of *ZrO*, *YO*, *LaO*; *TiO* usually present also	HR 1105 *R And*	Abundance of zirconium, etc.

BOOKS AND THE SKY

FLYING SAUCERS

Donald H. Menzel. Harvard University Press, Cambridge, 1953. 319 pages. $4.75.

IT IS the pleasant duty of astronomers to interpret the phenomena of the skies, leaving to the meteorologists only those effects that originate in the first few miles from here to infinity. During the past seven years there have been many flurries of excitement and a disturbing amount of confusion over so-called flying saucers. The question, "What are they?" has many answers, a good number of them astronomical.

Partial treatments, explanations of a few varieties of flying saucers, have always given a viewer opportunity to protest, "My flying saucer was different." What has been needed is a comprehensive but fast-reading exposition of the whole subject. Someone whose breadth of experience and authority can make headway against ignorance, delusion, prejudice, and desire for personal gain must be the author. All this we have in **Flying Saucers,** by the acting director of Harvard College Observatory, and it is a book of distinct importance.

The extreme type of flying saucer is, of course, imagined to be a disk-shaped interplanetary vehicle capable of navigating in defiance of gravity and of maneuvering under the direction of intelligent creatures, with a violence that would destroy any man-made structure and its human crew. It would be ridiculous to discuss this seriously were it not that a substantial number of people believe such things possible, enjoy holding this belief, and, furthermore, are convinced that some reports of flying saucers are best explained as sightings of such fantastic craft.

To wade into this situation, with so many skilled and unscrupulous writers committed to the false concept of flying saucers, took no little courage on Dr. Menzel's part. The challenge is not just the disillusioning of romantics who are titillated by the idea of meeting bigger and better boys from other worlds. The real issue is that "devotees of the saucer cult" are actively antiscientific and have rejoiced at unjustified criticism of the Air Force and its investigations.

In these circumstances, it is advantageous to have the entire history of flying saucers set forth in a volume which a lot of people are going to read. Before there was any question of airplanes or spaceships, a vast number of "signs in the sky" were described, starting with a Biblical account of sundogs, an ice-crystal phenomenon. This and many other effects come under the head of meteorological optics, a subject of great fascination.

From his studies of refraction and reflection due to discontinuities in the atmosphere, Dr. Menzel has found the obvious explanation of a large percentage of the most recalcitrant of the sightings. Temperature inversions, warm air above cold air, give rise to interfaces which make ground lights, and even radar beam reflections from buildings, appear to be high in the sky.

The basic false assumptions back of most flying saucer sightings fall in three categories. First is the conviction that the object is located where it is seen in the sky. Observers are reluctant to believe explanations involving reflections or refractions. Second is the belief that the observer can tell the composition of the object; many insist on "metallic luster," and so on. Actually, the eye can no more differentiate between gas, liquid, and solid than it can tell a direct view from a reflection. For example, the sun is gas-

NEW BOOKS RECEIVED

THE ATOM STORY, *J. G. Feinberg*, 1953, *Philosophical Library.* 243 pages. $4.75.

A general survey of the concept of the atom, from early Greek times to the era of the atomic bomb. The closing chapters consider the atom and the human race in peace and in war, and one appendix is a reprint of the United States government pamphlet, "Survival Under Atomic Attack."

THE NAMES OF THE STARS, *E. J. Webb*, 1952, *Nisbet and Co., Ltd.*, 22 Berners St., London W. 1. 206 pages. 15s.

A Greek scholar and amateur astronomer, the author has written a readable exposition in a field not recently covered in a full-length book. He applies his own thoughts to some of the problems of the origins of star names, and credits the Greeks more generally than do other writers. The work is published posthumously, as the author died in 1945; the editing was done by Ivor Bulmer-Thomas.

WAVES AND TIDES, *Russell and Macmillan*, 1953, *Philosophical Library.* 348 pages. $6.00.

Printed in Great Britain, this book consists of two parts, with each author responsible for one of the subjects of the title, and the discussion is for those interested in the sea, whether for pleasure or professionally. There is a good deal of astronomical material, especially in the second part. Most of the specific references and examples concern the British Isles.

STATISTICAL ASTRONOMY, *Trumpler and Weaver*, 1953, *University of California Press.* 644 pages. $7.50.

This textbook has as its purpose to introduce the student to the principal statistical problems in astronomy, to their mathematical formulation, and to methods and techniques of their solution. Considerable emphasis is placed upon relating the procedures used in stellar statistics to the principles of statistics.

THE SCIENTIFIC ADVENTURE, *Herbert Dingle*, 1953, *Philosophical Library.* 372 pages. $6.00.

Essays in the history and philosophy of science, drawn from lectures and addresses of the author, are divided into two parts in this collection, historical essays and philosophical essays.

THE STARS ARE YOURS, *James Sayre Pickering*, revised edition, 1953, *Macmillan.* 298 pages. $3.95.

A corrected printing of a book first published in 1948, devoted principally to constellations and star identification. Most of the errors pointed out by C. H. Cleminshaw in his review in *Sky and Telescope*, February, 1949, have been corrected or omitted, but numerous shortcomings are still noted. For instance, on page 56 is the phrase, "the 200-inch glass now in building," and the most recently discovered satellites of Uranus and Neptune are not included in the table on page 219. The bibliography lists one book that was never published, and is otherwise out of date in many respects.

eous, and a cloud consists of droplets, but both can exhibit sharp outlines. The most fundamental errors made by virtually all observers are the intuitive estimates of distance, on the rough accuracy of which they insist. In practice, at more than 100 feet, excellent pairs of eyes give the owners no measure of distance to unrecognizable objects against an elevated featureless background. For most people this limiting distance is less.

Dr. Menzel devotes considerable well-employed space to this question of distance measure. He should be able to convince all but the most sullen "saucerers" that most of the exciting reports involve wholly fallacious distance estimates and, of course, that all estimates of speed must be combinations of distance and angular motion guesses.

A major factor in bringing on the epidemic of flying saucers in our time has been the assumption that anything maintaining itself above the ground is more or less the size of an airplane or small spaceship. A sundog that looks about a degree in diameter caused by a well-known star 93 million miles away is readily transposed by the true believer in saucers to be a 200-foot disk at about two miles. A newspaper swept up in the air has given the same impression at half a mile.

Readers of **Sky and Telescope** will be particularly interested in the substantial number of flying saucers that have astronomical origins. Venus has been the cause of a great number of reports because most people are sure it is impossible for a "star" to be seen in daylight. Meteors and fireballs are naturally prolific breeders of saucer reports. In these cases the distance and speed estimates are always far too modest.

The aurora was involved in the best observed of all flying saucers, that of November 17, 1882. There had been a violent magnetic storm in the morning so there was good prospect of a display of northern lights. Astronomers of the Greenwich Observatory and many amateurs watched a brilliant aurora, in the middle of which a great cigar- or torpedo-shaped green light moved across the sky in something less than two minutes.

That was 70 years ago, and there is no definitive explanation of what variation on an ordinary aurora caused this "flying saucer." What is clear, however, is that it was not a tangible object moving through the atmosphere. The upper air was simply caused to glow.

Now that airplanes are common and interplanetary travel is the subject of several television programs, a flying saucer like the 1882 affair would be widely reported as a self-luminous spaceship. What Dr. Menzel has done so well is to show that all manner of strange and beautiful effects like this seen in the sky are simply natural phenomena.

Completely defeated by **Flying Saucers** are the people who insist that creations of superior intelligences from other worlds are necessary to account for some of the so-called "unexplained" sightings. Instead of getting into the position of merely denying that space saucers could be built somewhere in the universe, the author shows in full logic that there is no shred of evidence that any have been flown in the sight of man. He uses a light touch in disposing of those who would fly saucers on magnetic lines of force.

Among the many constructive features of this book is the best account currently in print, complete with excellent illustrations, of a consistent theory of aurora formation to which Dr. Menzel has himself made significant contributions. The illustrations throughout the volume are delightfully varied, with engaging old prints contrasted with diagrams made expressly for this work.

If we are to believe that the scientific point of view, the scientific method of securing information, prevails in modern civilization, there should be an end to the attitude that so many have taken regarding flying saucers. A considerable proportion of the public rejoices when an absurd report finds no scientific explanation. It is felt that the common man has, in a way, won a victory over the scientists.

It takes a scientist with a very human pen to fight this attitude at the front, to do as Donald H. Menzel has done in this book. He writes so all will read to the end. He proves that there is order throughout the universe, order which we may see and understand to the extent that we recognize our own limitations, the limitations of our senses.

JOHN W. STREETER
Fels Planetarium

THE UNIVERSE WE LIVE IN

John Robinson. Thomas Y. Crowell Co., New York, 1952. 252 pages. $4.50.

THIS BOOK purportedly takes the layman on a fascinating guided tour of the universe; it deals with selected subjects ranging all the way from exploding atoms to exploding mountains and stars. The first 10 chapters deal with essentially astronomical subjects, while the last four are concerned with bits of nuclear physics, volcanology, geology, and geophysics. The book is handsomely illustrated and some of the diagrams and points of view can be used with profit by a teacher of a beginning course in astronomy. The reviewer found the last three chapters to be especially interesting, although the geophysical discussion is highlighted by the author's complete acceptance of the controversial Wegener hypothesis of continental drift.

While there is undoubtedly a tremendous need for a book of this type to inform the interested layman concerning the universe about him—its past, present, and probable future—unfortunately this volume can be considered neither authoritative nor particularly up to date. For example, the author tends to confuse size with mass, mass with weight, temperature with energy, orbit with orbit plane, and so on. Most of the important astronomical developments of the past 10 years are conspicuous by their absence. The book has almost certainly not been critically edited by a professional astronomer. Such an elementary precaution on the part of the publishers would not have been expensive, inasmuch as it is well known that most astronomers will work at their profession for next to nothing!

JOHN B. IRWIN
Goethe Link Observatory

GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

Notes on Basic Optics

OUR CORRESPONDENCE indicates that it will be worthwhile to devote this department, at irregular intervals, to a series of discussions of what may be called "basic" optics, as distinguished from elementary optics. Optical texts are generally written for physics and optics students—most people who read this department do not find them generally interesting or useful. Nevertheless, although our treatment will be elementary in the extreme, we hope to work up very quickly to some important optical principles that are rarely discussed in either textbooks or courses in optics, but which are indispensable to an understanding of how optical systems work.

Basic optics will aid the amateur who seeks to have sufficient understanding of optical principles to be able to put a few lenses together to form a collimator, telescope, periscope, and the like, but who is not interested, for instance, in designing a photographic lens. We shall be presenting what Dr. John Strong has called "burning-glass optics." Readers are urged to write concerning the interest and value of the series; how far it will be carried will depend to a great extent on the nature of such comments.

A. Simple Lenses

1. **Description.** Everyone knows what a lens is—it is a piece of glass with curved surfaces that is used for optical purposes. The borderline cases of strange materials and queerly shaped surfaces we leave for possible discussion elsewhere. Here we are going to talk about the simple properties of lenses, and therefore we shall keep our lenses simple; they will be made of glass and their surfaces will be spherical or flat. Furthermore, we shall assume that the lenses have no thickness. This procedure immediately does away with a host of questions that would only confuse the issue at this stage.

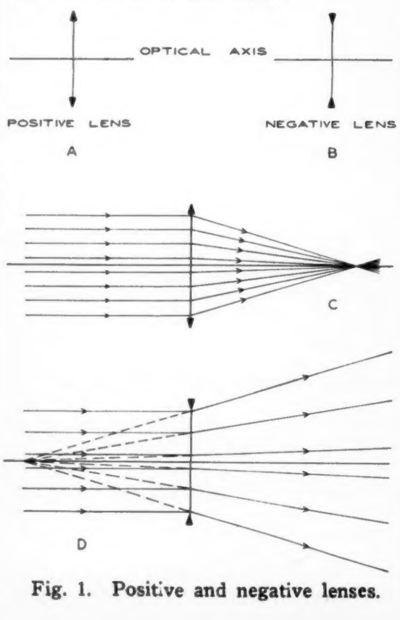


Fig. 1. Positive and negative lenses.

The reader, who is probably interested principally in mirrors, may ask why we talk about lenses first. The answer is that mirrors are considered as special cases of lenses; and it is in many ways better to use lenses to discuss basic principles.

If the lens has no thickness, we can represent it by a straight line, as in Fig. 1A and 1B. The lens has a property we call its focal length. This may be positive or negative. A positive lens converges the light rays that pass through it, as in Fig. 1C, and a negative lens diverges the light rays that pass through it, as in Fig. 1D. Thus, the lens has a positive or negative number assigned to it which is called its focal length. Later, we shall discuss how the construction of a lens and its material affect its properties.

2. **Images.** We may think of any object as a collection of points; from each point a bundle of light rays emerges, spreading out in all directions. If a lens intercepts a portion of one of these bundles of light rays, its converging or diverging action will cause the bundle, after it has passed through the lens, to converge at or diverge from a **different** point. This is called the image point.

If the light actually passes through the point, we might have the condition shown in Fig. 2A. This is called a "real" image. Sometimes, as in a negative lens (Fig. 1D), the light rays after passing through the

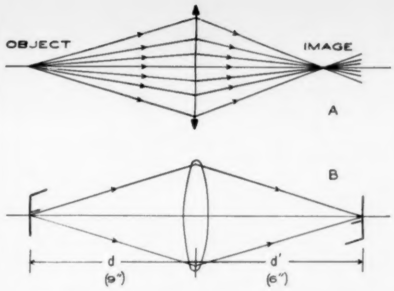


Fig. 2. The formation of images.

lens may merely appear to come from an image point without actually passing through it, in which case the image is called "virtual." This condition can occur in positive lenses as well as in negative ones, as we shall see.

Objects, however, are not usually points, but areas, and the image of an object area will be an area also (Fig. 2B).

There is a very simple mathematical relation that tells us where the image will be located. It is:

$$\frac{1}{\mathbf{d'}} - \frac{1}{\mathbf{d}} = \frac{1}{\mathbf{f}} \qquad (1)$$

where **d** and **d'** are the distances of image and object from the lens, and **f** is the focal length we talked about above. Some caution is necessary in using this equation. Distances to the left of the lens are negative, for the light is presumed to be traveling from left to right; distances to the right of the lens are positive. The focal length, **f**, must be given the proper sign for the lens concerned.

If we are careful about the arithmetic sign convention, we will always come up with the right answer. For example, in Fig. 2B, we would write $1/+6 - 1/-9 = 1/\mathbf{f}$, whence $\mathbf{f} = +3.6$ (inches). Were **f** known originally, the equation would have been solved for **d'**, which would have come out $\mathbf{d'} = +6$. Because this value is positive, it indicates that the image is to the right of the lens. This problem of the significance of algebraic signs may bother a student all through optics, so we point out its importance at the very beginning.

3. **Graphical Methods.** It is easy to find the image point by graphical means, and the method is often useful in checking calculations and for other purposes. Proceed as shown in Fig. 3A.

a. Mark the focal points $\mathbf{f}_1$ and $\mathbf{f}_2$ to the right and left of the lens, at distance **f** in each case. Note that for a positive lens

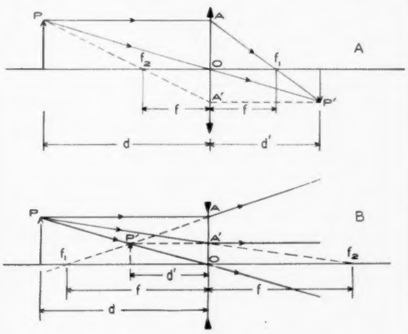


Fig. 3. Elementary ray tracing.

f_1 is laid out to the right and **f_2** to the left. For a negative lens the directions are reversed.

b. Draw the line **PA** parallel to the optical axis, and then the line **Af₁** extended, through the focal point **f_1**.

c. Draw **PO** extended through the center of the lens.

d. The lines **Af_1** and **PO** meet at **P′**; this is the image point.

e. If desired, **PA′** may be drawn through **f_2**, and then the line from **A′** parallel to the axis. This will also pass through **P′**.

f. Any two of the three lines are sufficient for the construction of **P′**.

If the lens were negative, **f_1** and **f_2** would be interchanged, but the procedure would be identical. The picture would look like Fig. 3B. In this case, **P′** lies to the left of the lens, as we might expect, for the particular distance chosen for **P**. In either case, the distances **d, d′**, and **f** will always agree with Equation 1, in both magnitude and sign.

If desired, this construction may be used to trace the course of any ray whatsoever through a lens, a useful procedure at times. This is anticipating future discussions a little, but let us go through the procedure while we have ruler and pencil handy.

Consider a ray, **RB**, and the lens of Fig. 4. Pick any point, **P**, at random. Make the construction described above for the image, **P′**, of **P**, using any two of the three rays shown. Finally, draw the ray **BP′**. This is the course of the ray **RB** after it has passed through the lens.

4. **Discussion.** It is clear, of course, that in the foregoing work we have made some assumptions that are not strictly true. We have, for example, assumed that a lens will converge (or diverge) any bundle of light to a perfect image point.

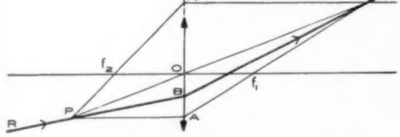


Fig. 4. The course of any ray.

Naturally, lenses do not do this in practice. But there is a very neat way of getting around this practical difficulty, which makes what we have just said not an abstract discussion but a useful tool in optical design. It is this: Any failure of a lens to do what we have assumed above is called an aberration, and complex mathematical processes have been developed for discussing these effects by themselves.

Actually, lenses come very close to doing what we have described here as long as the conditions of the problem are kept simple; therefore, we are perfectly justified in developing the present discussion around an ideal lens and leaving aberrations as a separate topic.

This simplified treatment is known as first-order theory or Gaussian optics, and is all too often, we feel, considered beneath the dignity of a real optical designer. This is something like saying that to distinguish a vegetable from a weed is beneath the dignity of an agriculturist. The distinction is obviously very useful for a farmer.

(To be continued)

DEWING PREVENTION FOR REFRACTOR ELEMENTS

To PREVENT moisture from entering an air-spaced refractor objective, first be sure the air between the elements is perfectly dry. Then take a small artist's brush and run hot beeswax around the inside rim of the objective cell, on both the perimeter of the objective where it enters the cell and the cell metal itself. Be sure to use beeswax, which is impervious to moisture, whereas paraffin is not.

The beeswax should be placed in a small tin box lid, and kept melted, but just below its boiling point. You cannot apply more than an inch length of this sealing at a time, since the wax on the brush cools too quickly. Make a quick application with a stroke of the brush, then dip the brush for the next application. Do not worry about cracking the objective, for the beeswax cools too quickly to heat the glass.

This method may be used for college observatory objectives as well as for smaller portable instruments. After both the crown and flint sides of the objective and cell have been sealed, scrape off the surplus wax with a flat end of a small piece of wood or thick cardboard, leaving a rim from the cell on the glass about 1/16″ to 1/32″.

The rear element of an objective rarely dews up, as it is inside the main tube, which is usually fairly well closed. Dewing on the outer surface of the objective can, of course, be largely prevented with a dew cap, its length about three times the aperture of the lens. Line the interior of the dew cap with two layers of desk blotting paper that has been gently heated before observing; place the blotter on a radiator or any other suitable heat source.

The prevention of dewing is especially important, for when it occurs the night is likely to be a good one, as there are a minimum of air currents that cause unsteadiness of star images. I have seen observation parties ruined on good nights, when refractors up to 10 inches in diameter have become dewed between the elements.

FRANK L. GOODWIN
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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Searching for Comets

IN SEARCHING for comets, a 5-inch refractor on an altazimuth mounting is an ideal instrument. One does not use a large telescope, nor a high power, for should a large instrument be used it would show so many cometlike objects that the observer would be kept busy identifying them. A 5-inch telescope with a power of about 45 takes in a field of about one degree square, or a space the size of four full moons.

In this work a conventionally mounted reflecting telescope is awkward to handle, usually requiring a ladder of some kind, but an instrument of short focal length can probably be employed satisfactorily. A 4- or 5-inch reflector with short focal length six or eight times the diameter of the glass, with a low mount, could be very nicely used without steps or ladder even when an object is directly overhead. Such a telescope would not need a dewcap as the tube would take its place.

In the case of a refractor, when the observer wishes to reach high altitudes and avoid stooping, he raises the tripod, which, at most, needs to be done once or twice during the evening. Sweeping is carried on until a star bright enough to be identified with the naked eye comes into the field, and this star can then be used as a marker for the beginning of further sweeping after the tripod raising is made. The tripod should be very heavy and sturdy in order that there will be no quiver and that objects will pass through the field smoothly and clearly. A dewcap about 14 inches long is essential in keeping condensation from the lens. On many evenings moisture will condense where there is seemingly little moisture in the air. A small amount of such condensation, if the lens is not protected, can very easily spoil an evening's work.

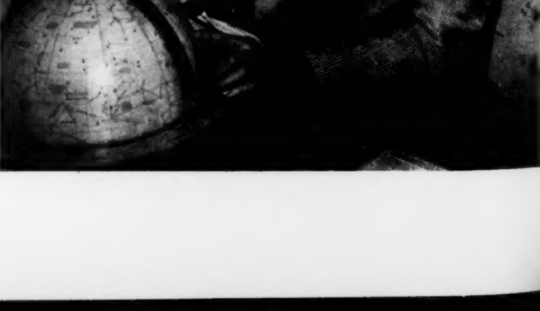
Sky conditions must be good. On a scale of 10, seeing must be 7 to accomplish anything in the way of picking up comets. The moon must be out of the way. The evening sky to the east of the sun is lighted too brightly by the moon to see faint comets from before the first quarter until after the full moon. Occasionally a comet has been discovered so near moonrise that the observer was unable to locate his discovery accurately until the next night.

Start observations the first clear evening after the full moon. Begin at the "grass roots," 90 degrees north or south of the sunset point, and sweep along the horizon, past the sunset point to as far on the other side. Move the telescope up half a degree and repeat the process until the sweep carries you 90 degrees or more east of the sun. In sweeping the morning sky, start 90 degrees or more west of the sun, lower the telescope half a degree eastward after each sweep and carry on until the rays of the rising sun make the sky too bright for observations to be continued.

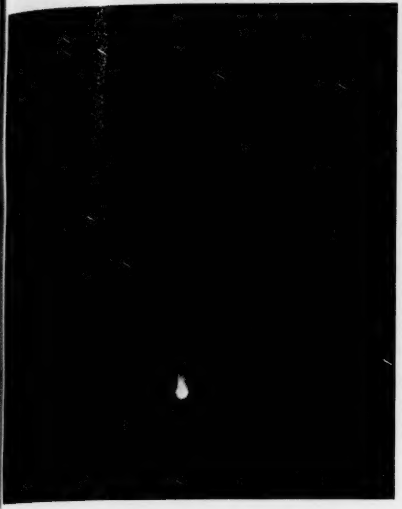
Be sure not to miss any portion of the area being swept. That might be just the place where a comet is lurking. In working across the sky, move the instrument very slowly in order that any minute object may be picked up. A faint comet may be very easily passed over without discovery.

Most comets come within the orbit of the planet Mars before they are bright enough for visual discovery. They are most often found within 90 degrees of the sun; however, comets may appear anywhere in the sky. Nevertheless, as some regions of the sky contain a great many nebulae and star clusters which may be mistaken for comets, one cannot search everywhere. For instance, an amateur should never waste time sweeping in the region of Virgo, since there are more than 400 cometlike objects in that flowery meadow. A good star atlas such as Norton's or the Skalnate Pleso is essential for checking the identity of nebulous objects.

There is a great variety in appearances of comets when they are first picked up. Some appear as a small fuzzy spot, and very faint; others have a sharp bright nucleus; while still others are as intricate as a piece of fine lace. Cometary motions differ also. The late Dr. E. E. Barnard, of Yerkes Observatory, discovered a comet that moved across the entire sky in one night. This was not reported by Dr. Barnard, and as it did not appear the second night, no record was ever made of it. Some comets picked up near the sun are visible only for a few nights, while one



Clarence L. Friend, who found his first comet on April 18, 1939, as one of the independent discoverers of Comet Jurlof-Achmarof-Hassel, pictured on the opposite page. On November 1st of the same year he found his second comet, of the 10th magnitude. On January 16, 1941, he discovered a comet that was confirmed by Reese; and on November 22, 1945, he found a fourth comet, independently discovered by Peltier two days later.



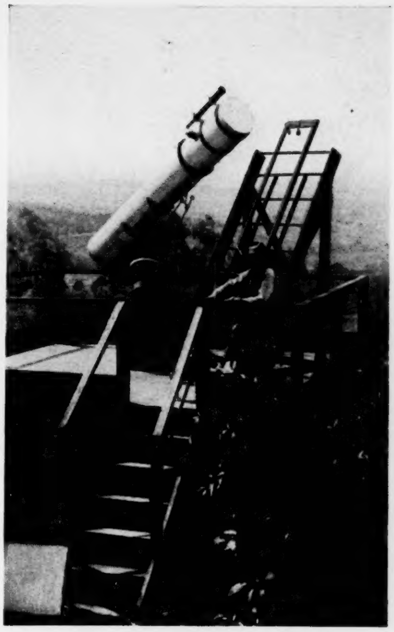
This comet, Jurlof-Achmarof-Hassel, had many independent discoverers, among them Clarence L. Friend (his first). It was first found by the Russian amateurs, Jurlof and Achmarof, on April 15, 1939. The comet was of the 3rd or 4th magnitude with a long tail, but after a few days it developed two tails, shown in this photograph taken on April 23rd, with the 12-inch refractor of Harvard's Agassiz station. By about May 10th, it had lost its tails completely and had faded to the 7th magnitude. Harvard Observatory photograph.

was in the sky for 18 months. A comet discovered by the writer (Comet Friend #3) lacked but two degrees from going straight up from the western horizon. (Any object traveling at right angles to the ecliptic is going "straight up.")

Should an amateur, whether searching for a comet or not, run across a cometary object of which he is not sure, he should locate some star or configuration of stars to be used as a marker, then go to his atlas and attempt to find the configuration and thus check the object. Of course the final check is to see if the object moves. The observer may continue his search or other observations, but he should occasionally select a star in the field to be used as a marker to which he can return, and then go back to the suspicious object to see if it has a new position. Sometimes movement can be detected in as few as five minutes but usually a longer time is required. It all depends upon the manner in which the comet is coming in, or, perhaps, moving out from the sun. It is much more difficult to detect the motion of the comet when it is moving approximately toward or away from the earth.

When an observer is certain he has made a discovery, he should check Harvard Announcement Cards to be sure he has not come upon a previously known object. Also he should check the current **Handbook** of the British Astronomical Association, where comet orbits and positions are predicted. If satisfied that his new object is unknown, he should telegraph Harvard College Observatory, Cambridge, Mass., giving the comet's right ascension and declination (north or south), its apparent integrated magnitude, and if possible its apparent motion across the sky, both as to speed and direction. The speed should be the number of minutes of arc hourly, or the number of degrees daily, and should be divided into its components in right ascension and declination.

The principal requirement is: **Don't be discouraged.** If you are persistent and keep continually at it, you will almost certainly be rewarded even though it takes years. Six years sweeping the sky night and morning each month does not seem very encouraging. Yet to the present writer the seventh year paid off, and handsomely too. So don't give up. If you do not have a 5-inch refractor, use any good available telescope. Get into the game and stay in.



Although Mr. Friend has a refractor for his comet seeking, much of his other observing is done with this 16-inch reflector, principal instrument of his El Amigo Observatorio.

CLARENCE L. FRIEND
Bear Valley Rd.
Escondido, Calif.

MAY METEORS

The Eta Aquarid meteor shower may be observed the first week of May during the morning hours. Rates of 10 meteors per hour are predicted under favorable conditions at maximum on May 4th. The last-quarter moon will be in the sky but should not interfere seriously.

E. O.

SUNSPOT NUMBERS

February 1, 1, 0; **2**, 9, 7; **3**, 10, 8; **4**, 10, 8; **5**, 10, 8; **6**, 12, 8; **7**, 13, 14; **8**, 11, 8; **9**, 13, 7; **10**, 10, 7; **11**, 8, 7; **12**, 2, 0; **13**, 1, 0; **14**, 0, 0; **15**, 1, 0; **16-28** inclusive, 0, 0. Means for February: 4.0 American; 2.9 Zurich.

Daily values of the observed mean relative sunspot numbers are given above. The first are the American numbers computed by Neal J. Heines from Solar Division observations; the second are the Zurich Observatory numbers.

SKY-GAZERS EXCHANGE

DEEP-SKY WONDERS

TO OBSERVERS of intergalactic deeps, May brings visions of the great clouds of spirals that dominate Virgo, Coma Berenices, and Canes Venatici. Less realized, perhaps, is that in these same regions we get the first onrushers of the globular clusters which finally swarm in their greatest profusion around the galactic center in Scorpius-Ophiuchus-Sagittarius.

Three globulars are within the narrow limits of Coma itself, including two that lie near Alpha. NGC 5024, also dignified as M53, $13^h\ 10^m.5$, $+18°\ 26'$, is 14.4 minutes in diameter with a magnitude of 8.7. Unimpressive in a 3-inch refractor, its star sprinklings are magnificent in a 12½-inch reflector, where faint streams of curving stars run out from the central blaze in all directions. Smyth called it an "interesting ball of innumerable worlds."

Almost in the same field is NGC 5053, 7^6, $13^h\ 13^m.9$, $+17°\ 57'$, diameter 8'.9, magnitude 10.9. This is not plotted on any atlas except the Skalnate Pleso that I have seen. It should be, for in larger instruments it is a little gem of weaving fairy fire. Dr. Helen Sawyer Hogg's **Bibliography of Individual Globular Clusters** (University of Toronto Press, 1947), shows that it was first observed by W. Herschel on March 14, 1784. It is remarkable for its position in space, perhaps 50,000 light-years above the galactic plane.

Considerably to the west of these two lies NGC 4147, 19^1, $12^h\ 7^m.6$, $+18°\ 49'$, 4'.1, magnitude 11. Its faintness misled Herschel, on the same date as that above, into listing it as an external galaxy, and only with the great reflectors of the 20th century could its individual stars be seen well and studied. We now know of at least several variable stars in this faint object.

In the same field lies a true faint external galaxy, NGC 4153, 11^1, about 13' south and about 8' east. It is not listed in the Shapley-Ames catalogue, and hence must be fainter than 13th magnitude. It would be a real feat for an amateur scope to locate it. This writer has examined NGC 4147 on half a dozen occasions without noticing the faint galaxy.

WALTER SCOTT HOUSTON

MOON PHASES AND DISTANCE

Last quarter	May 6, 12:21
New moon	May 13, 5:06
First quarter	May 20, 18:20
Full moon	May 28, 17:03
Last quarter	June 4, 17:35

May		Distance	Diameter
Perigee	10, 5^h	227,200 mi.	32' 41"
Apogee	22, 2^h	251,200 mi.	29' 33"
June			
Perigee	5, 14^h	229,700 mi.	32' 20"

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.

MARE IMBRIUM MEASUREMENTS

A mimeographed catalogue of secondary positions of some 490 objects in Mare Imbrium has been published by D. W. G. Arthur. It is 15 pages long, and is entitled **A Minor Triangulation of the Mare Imbrium;** an introduction outlines the method of measurement and reduction of points on a 100-inch photograph of this region of the moon. In a private communication, the author expresses the hope that "this network of fixed points will make it possible for someone to draw up a really good map of the Mare Imbrium."

American purchasers may send three shillings by international money order to the author at 17 Waterloo Rd., Wokingham, Berks, England. A previous publication by Mr. Arthur, on lunar crater diameters, was described on page 100 of the February, 1952, issue.

A SWISS PLANISPHERE

"SIRIUS" is the name of a new planisphere, by M. Schuerer and H. Suter, that has been published by the Astronomical Society of Berne. On heavy cardboard 15 by 15 inches are mounted circular star charts, one for each hemisphere, showing stars to magnitude 5.5, constellation outlines, boundaries, and many special objects. The planisphere masks are of heavy transparent plastic, with the horizon circles drawn for latitudes 47° north and 34° south. Additional cover sheets for other latitudes are available, at a cost of two dollars each.

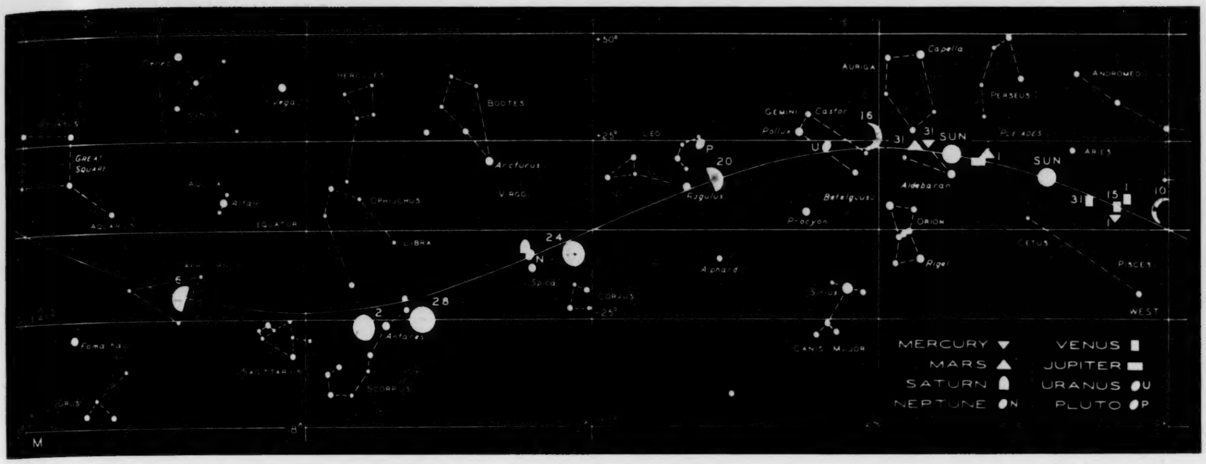
A rotating transparent pointer mounted under the mask is marked into degrees of declination. The usual dates for the mean sun on the periphery of each chart are supplemented by two additional sets of markings, one showing hours and minutes of right ascension and one for the true sun. The northern chart is plotted southward to −54°, and the southern chart extends to +54°. Supplementary planet sheets and some English explanatory notes may be requested. The inscriptions on the chart, such as names of months, are in Latin.

The well-plotted star charts contain several hundred special objects, including double stars, variables, galactic and globular clusters, and galaxies.

The entire assembly is sturdily constructed and is machined to a high degree of accuracy, making the planisphere suitable for determining local time, the position of the horizon line being known by the rising or setting of a celestial object, or by its transit across the meridian. A special scale is provided for observations of Polaris when that star is at upper or lower transit, or at eastern or western elongation. The times of sunrise and sunset may also be predicted, to the nearest minute, as refraction and radius of the sun have been allowed for.

This new planisphere may be purchased directly from the Astronomische Gesellschaft Bern, Balmweg 37, Berne, Switzerland. Including mailing expenses, the prices are: $8.50 for the chart with one cover sheet; $10.00, with two cover sheets. Communications may be addressed to the attention of Ernst F. Plattner.

C. A. F.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury will be too close to the sun this month for viewing. The planet passes superior conjunction with the sun on May 24th, entering the evening sky.

Venus, brilliant in the morning sky, appears at maximum brightness on May 19th, at magnitude −4.2. Rising about 1¾ hours before the sun on that date, Venus presents a crescent 38″ in diameter, with 26% of the disk illuminated. As the planet may be viewed during the day about this time, it can be watched after sunrise without difficulty.

Mars may be seen as a 2nd-magnitude object after sunset for a short time early in May, but will be lost in the twilight later in the month.

Jupiter, also visible low in the west the first week in May after sunset, is below Mars but is considerably brighter. Conjunction with the sun occurs on May 25th, with Jupiter reappearing in the morning sky next month.

Saturn will be the only naked-eye planet visible most of the night. Moving in retrograde motion in Virgo, Saturn passes conjunction with Spica on May 24th, the planet 5° 7′ north. Seven days later, the second of a series of three conjunctions of Saturn and Neptune takes place, Saturn 1° 2′ to the north. The ring system in mid-May appears inclined 12°.3 to our line of sight; its major diameter is 42″.5, with the northern face visible.

Uranus, an evening-sky object moving eastward toward Delta Geminorum, is about 2° west of the star, and may be viewed with slight optical aid. Charts in the February issue, page 113, show the positions for Uranus and Neptune during 1953.

Neptune, located about 1° south of Saturn at the end of May, requires moderate-sized binoculars for viewing. The planet continues in retrograde motion; it is well placed for observation, on the meridian about 10 p.m. local time.

E. O.

VESTA VISIBLE

Positions and other information concerning the four brightest minor planets are published in the 1953 **American Ephemeris.** For Vesta, brightest of these, the first position is for May 5th, although opposition will not be reached until August 18th, when the asteroid will be of magnitude about 6.4, and its distance from the earth will be 1.27 astronomical units. On May 8th it will be at a distance of two astronomical units, and may be found about two degrees northwest of Gamma Capricorni. A plot of the following positions on a star atlas should permit its identification. Right ascension is given after the date, then declination to the nearest minute.

May 5, 21:28.0, −16-06; 11, 21:36.1, −15-46; 17, 21:43.7, −15-28; 23, 21:50.6, −15-14; 29, 21:56.9, −15-04.

June 4, 22:02.4, −14-59; 10, 22:07.2, −14-59; 16, 22:11.0, −15-05; 22, 22:13.9, −15-18; 28, 22:15.8, −15-38.

July 4, 22:16.7, −16-04; 10, 22:16.4, −16-37.

Vesta will be stationary in right ascension on July 5th, when its retrograde motion will begin. For several days at this time, it will be near a position about midway between the stars plotted in Norton's **Star Atlas** as 39 and 53 Aquarii, in a region of several square degrees in which it will be the brightest object.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Victoria, 12, 8.7. May 3, 16:33.8 −21-38; 13, 16:27.6 −20-22; 23, 16:19.2 −18-55. June 2, 16:09.8 −17-23; 12, 16:01.0 −15-55; 22, 15:54.4 −14-41.

Daphne, 41, 8.8. May 13, 16:52.6 +4-19; 23, 16:46.6 +4-49. June 2, 16:39.6 +6-42; 12, 16:32.7 +6-58; 22, 16:27.1 +6-38. July 2, 16:23.9 +5-43.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1953.0) for 0ʰ Universal time. In each case the motion of the asteroid is retrograde. Data supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

VARIABLE STAR MAXIMA

May 1, S Carinae, 1006**61**, 5.7; 8, V Bootis, 142539, 7.9; 9, R Corvi, 1214**18**, 7.6; 22, R Serpentis, 154615, 6.8; 22, RT Cygni, 194048, 7.4; 24, S Canis Minoris, 0727**08**, 7.5; 26, RR Scorpii, 1650**30**, 6.0; 27, R Leonis, 094211, 5.9. June 5, Z Ursae Majoris, 115158, 6.6.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

OCCULTATION PREDICTIONS

May 2-3 **66 B Sagittarii** 4.7, 18:15.1 −27-03.7, 20, Em: **F** 10:44.4 −2.2 +0.4 245; **G** 10:16.3 −1.5 +0.3 279; **H** 9:57.0 −2.1 +0.9 259; **I** 10:01.9 −1.4 +0.7 276.

May 5-6 **Theta Capricorni** 4.2, 21:03.3 −17-25.2, 23, Im: **A** 7:08.4 −0.9 +0.7 121. Em: **A** 7:51.3 −1.1 +2.5 196; **B** 7:57.1 −1.0 +2.2 201; **C** 7:36.2 −1.1 +3.2 187; **D** 7:46.9 −1.1 +2.5 199.

May 27-28 **Pi Scorpii** 3.0, 15:56.0 −25-58.8, 15, Im: **E** 8:32.3 −1.7 −1.9 127; **F** 8:37.7 −2.3 −2.6 143; **G** 7:41.6 −1.5 −0.5 110; **H** 7:40.8 −1.9 −1.1 133; **I** 7:28.0 −1.5 −0.2 116. Em: **F** 9:29.6 −0.6 +0.6 224; **H** 8:57.0 −2.1 −0.1 251; **I** 8:45.8 −1.6 −0.5 269.

For standard stations in the United States and Canada, for stars of magnitude 5.0 or brighter, data from the **American Ephemeris** and the **British Nautical Almanac** are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**Lo — LoS**), and multiply **b** by the difference in latitude (**L — LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.6	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	+114°.0,	+50°.9
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
I	+123°.1,	+49°.5			

HERE AND THERE WITH AMATEURS

*Members receive *Sky and Telescope* as a privilege of membership. †Member organizations of the Astronomical League.

State	*City*	*Organization*	*Time*	*Meeting Place*	*Communicate With*
ARIZONA	Phoenix	*Phoenix Obs. Ass'n.	7:30, 1st, 3rd, Tue.	Private homes	R. W. Smith, Jr., 6635 N. Central Ave.
CALIFORNIA	Fresno	Central Val. A.S.	7:45, 2nd Mon.	Fresno Coll., Homes	Mrs. Virginia Byrd, 409 Shields Ave.
	Kentfield	*Marin Am. Ast.	8:00, 4th Fri.	Marin College	Mrs. I. Osborn, 223 Santa Margarita, San Rafael
	Long Beach	†*Excelsior Tel. Club	7:30, 3rd Fri.	Art Center	T. R. Cave, Jr., 265 Roswell Ave. (3)
	Los Angeles	L.A.A.S.	7:45, 2nd Tue.	Griffith Obs.	G. Carroll, 7114 Summitrose St., Tujunga
	Oakland	*Eastbay A.S.	8:00, 1st Sat.	Chabot Obs.	Miss A. Roemer, 1556 Everett, Alameda
	Palo Alto	*Peninsula A.S.	7:30, 1st Fri.	Community Center	H. W. Milner, 350 Tennyson Ave.
	Redlands	*Redlands A.S.	7:30, Tues.	Univ. of Redlands	Miss R. Schweikert, 111 Prospect Dr.
	Sacramento	*Sac. Val. A.S.	8:00, 1st Tue., bi-mon.	Sacramento College	Mrs. E. Champ, 3816 Sacramento Blvd. (17)
	San Diego	Ast. Soc. of S.D.	7:30, 1st Wed.	504 Electric Bldg.	W. T. Skilling, 3140 Sixth Ave.
	San Diego	A.T.M. Ast. Club	7:30, 2nd, 4th Mon.	3121 Hawthorn St.	G. A. Sharpe, 4477 Muir, Bayview 3757
	San Francisco	*S.F. Am. Ast'mers	8:00, 1st Wed.	Randall Junior Mus.	H. A. Wallace, 2925A Jackson St.
	Stockton	*Stockton A.S.	8:00, 2nd Mon.	Stockton College, P-11	C. D. Corwin, 1427 N. Center St. (3)
COLORADO	Denver	†*Denver A.S.	8:00, 2nd, 4th Mon.	Chamberlin Obs.	Kenneth Steinmetz, 4282 Grove, GR 9143
CONNECTICUT	Middletown	*Centr. Conn. A.A.	8:00, 1st Tue.	Van Vleck Obs.	Walter Fellows, Middle Haddam
	New Haven	†A.S. of New Haven	8:00, 4th Sat.	320 York St.	Mrs. Helen Velardi, 437 Wash., N'th Haven
	Norwalk	*Perkins-Elmer AA&TM	5:00, 1st, 3rd, Wed.	Perkin-Elmer plant	J. Vrabel, Bob White Lane, Wilton
	So. Norwalk	†Fairfield Co. A.S.	8:00, Alt. Fri.	Private homes	Goldie L. Grantham, 58 Bouton St.
	Stamford	Stam. Museum A.A.	8:00, 3rd Fri.	Stamford Museum	R. F. Ives, Post Rd. East, Darien
DIST. COL.	Washington	†Nat'l. Cap. Ast'mers	8:00, 1st Sat.	Comm. Dept. Audit.	Mrs. G.R. Wright, 202 PipingRk.Dr., Silv. Spr., Md.
FLORIDA	Daytona Beach	D. B. Stargazers	8:00, Alt. Mon.	105 N. Halifax Ave.	Wm. T. Thomas, 105 N. Halifax
	Jacksonville	†*J.A.A.C.	8:00, 1st, 3rd, Mon.	Private homes	E. L. Rowland, Jr., 442 St. James Bldg.
	Key West	†Key West A.C.	8:00, 1st Wed.	Private homes	J. M. Martin, 1605 United St.
	Miami	†*South'n Cross A.S.	7:30, 3rd Mon.	Central School	A. P. Smith, Jr., 426 S.W. 26 Rd.
	Miami Springs	†*Gulfstream A.A.	8:00, 4th Fri.	Armory, U. of Miami	L. G. Pardue, 641 Falcon, 88-5434
	Pensacola	†Pensacola A.A.C.	7:30, 3rd Mon.	Private homes	Frank Dachille, 1781 E. Baars St.
GEORGIA	Atlanta	†*Atlanta A.C.	7:30, 2nd Fri.	Agnes Scott College	W. H. Close, 225 Forkner Dr., Decatur
ILLINOIS	Chicago	†*Burnham A.S.	4:00, 2nd Sun.	Adler Planetarium	J. A. Anderer, 7929 S. Loomis Blvd. (20)
	Geneva	*Fox Valley A.S.	8:00, 1st Tue.	Geneva City Hall	Joseph Zoda, 420 Fellows St.
	Moline	†*Popular A.C.	7:30, Wed.	Sky Ridge Obs.	Carl H. Gamble, 3201 Coaltown Rd.
INDIANA	Indianapolis	†*Indiana A.S.	2:15, 1st Sun.	Riley Library	Clark B. Hicks, 305 Ruckle St.
	South Bend	St. Jos. Valley Ast.	8:00, 1st Mon.	Hotel La Salle	Miss I. DeBruycker, 1023 S. Union, Mishawaka
KANSAS	Wichita	†*Wichita A.S.	8:00, 1st Wed.	214 East High Sch.	S. S. Whitehead, 2322 E. Douglas, 62-6642
KENTUCKY	Louisville	†L'ville A.S.	8:00, 1st Tue.	Univ. of Louisville	B. F. Kubaugh, 207 Sage Rd. (7)
LOUISIANA	New Orleans	A.S. of N.O.	8:00, Last Wed.	Cunningham Obs.	Dr. J. Adair Lyon, 1210 Broadway
MAINE	Portland	†A.S. of Maine	8:00, 2nd Fri.	Private homes	H. Harris, 27 Victory Ave., S. Portland
MASSACHUSETTS	Cambridge	†*Bond A.C.	8:00, 1st Thu.	Harvard Obs.	Dr. Dorrit Hoffleit, Harvard Observatory
	Cambridge	†*A.T.M.s of Boston	8:00, 2nd Thu.	Harvard Obs.	John Patterson, 142 Elgin, Newton Centre 59
	Cambridge	*M.I.T. A.S.	7:30, Alt. Wed.	Mass. Inst. Tech.	R. L. White, Bx. 162, 3 Ames St.
	Springfield	†*S'field Stars	8:00 2nd Wed.	Private homes	J. E. Welch, 107 Low'r B'verly Hills, W. S'field
	Worcester	†*Aldrich A.S.	7:30, 1st, 3rd Tue.	Mus. Natural Hist.	W. C. Lovell, 24 Courtland (2), 3-1559
MICHIGAN	Ann Arbor	†Ann Arbor A.A.A.	7:30, 2nd Mon.	U. of Mich. Obs.	Stewart W. Taylor, 1106 Birk Ave.
	Battle Creek	†B. C. Ast. Club	8:00, 2nd Fri.	Kingman Museum	Mrs. W. V. Eichenlaub, 47 Everett St.
	Detroit	†*Detroit A.S.	2:30, 2nd Sun.	Wayne U., State Hall	E. R. Phelps, Wayne University
	Kalamazoo	†Kalamazoo A.A.A.	8:00, Sat.	Private homes	Mrs. G. Negrevski, 2218 Amherst, 31482
	Lansing	†*Lansing A.A.	8:00, Fri.	Private homes	Edward H. Carlson, 2111 Grant St. (10)
	Pontiac	†*Pon.-N.W. Det. A.A.	3:00, 3rd Sun.	Cranbrook Inst.	G. Carhart, 40 Hadsell Dr., FE 2-9980
MINNESOTA	Minneapolis	M'polis A.C.	7:30, 1st, 3rd Wed.	Public Library	Jane Simmer, 2406 Clinton Ave. S.
	St. Paul	†*St. Paul Tel. Club	7:30, 2nd, 4th Wed.	Macalester Coll.	Mrs. R. E. English, 1283 Sargent Av.
MISSOURI	Fayette	†*Central Mo. A.A.	7:30, 3rd Sat.	Morrison Obs.	R. C. Maag, 816½ S. Mass., Sedalia
	Kansas City	†*A.C. of Kans. City	8:00, 4th Sat.	Private homes	Mrs. Laura Kinsey, 4604 Jefferson (2)
	St. Louis	†*St. Louis A.A.S	8:00, 3rd or 4th Fri.	Inst. of Tech., St. L. U.	S. O'Byrne, 501 E. Pacific, Webster Groves 19
NEVADA	Reno	A.S. of Nev.	8:00, 4th Wed.	Univ. of Nevada	E. W. Harris, University of Nevada
NEW JERSEY	Caldwell	West Essex A.A.	8:00, 2nd Mon.	Caldwell Mun. Bldg.	Walter J. Adams, 18 Thomas St.
	Jersey City	†Revere Boys Club	7:15, Mon., Tue.	Gregory Mem. Obs.	Enos F. Jones, 339 Wayne St.
	Roselle Park	†A.A.S. of Union Co.	...., 4th Fri.	Boro Hall	Mrs. R. N. Bochau, 236 Normandy Vill., Union
	Rutherford	A.S. of Rutherford	8:00, 1st Thu.	YMCA	W. B. Savary, 78 W. Pierrepont Ave.
	Teaneck	†Bergen Co. A.S.	8:30, 2nd Wed.	Obs., 107 Cranford Pl.	J. M. Stofan, 332 Herrick
NEW MEXICO	Las Cruces	†*A.S. of L.C.	...., 1st Sat.	Private homes	C. W. Tombaugh, 636 S. Alameda
	Roswell	*Pecos Val. S&TC.	7:30, 2nd Sat.	Cha. of Comm.	Dr. R.R. Boyce, Rt. 2, Bx. 163A
NEW YORK	Buffalo	†*Buffalo A.A.	7:30, 1st Wed.	Mus. of Science	Dr. F. S. Jones, 83 Briarcliffe, Cheektowaga (25)
	Corning	Corning A.C.	8:00, 1st, 3rd Mon.	Corning Glass Center	W. R. Redmond, 119 E. 2nd St.
	Gloversville	†*A.C. of Fulton Co.	...., ...	....	L. R. Ogden, 60 W. Pine St.
	New York	*A.A.A.	8:00, 1st Wed.	Amer. Mus. Nat. Hist.	G. V. Plachy, Hayden Plan., TR 3-1300
	New York	†Junior A.C.	8:00, 3rd Fri.	Amer. Mus. Nat. Hist.	J. Rothschild, Hayden Plan., TR 3-1300
	Rochester	†Rochester A.C.	8:00, Alt. Fri.	Rochester Museum	Peggy Lagen, 34 S. Goodman St. (7)
	Schenectady	†*S'tady A.C.	7:30, 3rd Mon.	Nott Terrace H.S.	C. E. Johnson, 102 State St.
	Troy	*Renss. Ap. Soc.	7:30, Alt. Tue.	Sage Lab., R.P.I.	Dr. Robert Fleischer, R.P.I.
	Utica	†*Utica Am. Ast'mers	7:30, 4th Tue.	Proctor Inst.	John Zimm, 239 Thieme Pl.
	Wantagh	Long Island A.S.	8:00, Sat.	Private homes	A. R. Luechinger, Seaford Ave., 1571
N. CAROLINA	Greensboro	†*Greensboro A.C.	8:00, 2nd Wed.	Woman's Coll., U.N.C.	Mrs. J. Bradshaw, Guilford College, N.C.
	Raleigh	†Astronomical Soc.	...., 1st, 3rd Thu.	N. C. State Coll.	Richard C. Davis, Sch. of Textiles
	Winston-Salem	†*Forsyth A.S.	7:30, Last Fri.	Private homes	Kenneth Shepherd, 1339 W. 4th St.
OHIO	Akron	*A.C. of Akron	8:00, 2nd Fri.	Beth.-Luth. Church	Mrs. R. J. Couts, 878 Kennebec Ave. (5)
	Cincinnati	*Cin. A.A.	8:00, Various days	Cincinnati Obs.	Robert Berkmeier, 2432 Ohio Ave.
	Cincinnati	*Cin. A.S.	8:00, 3rd Wed.	5556 Raceview Ave.	John Dann, 3318 Felicity Dr. (11)
	Cleveland	†Cleveland A.S.	8:00, Fri.	Warner & Swasey Obs.	Mrs. A. Townhill, Warner & Swasey Obs.
	Columbus	*Columbus A.S.	8:00, 2nd Sat.	McMillin Obs.	Miss R. A. Charlton, 1361 E. 22 Ave. (11)
	Dayton	A.T.M.s of Dayton	Eve., 3rd Sat.	Private homes	F. E. Sutter, RR 7, Box 253A (9)
	Lorain-Elyria	*Black River A.S.	7:30, 2nd Tue.	Lorain YMCA	Louis Rick, Box 231, Lorain
	Marietta	Marietta A.S.	Irregular	Cisler Terrace	Miss L. E. Cisler, Cisler Terrace
	Toledo	Toledo Ast. Club	...., 3rd Tue.	Univ. of Toledo Obs.	E. D. Edenburn, 4124 Commonwealth Ave.
	Warren	Mahoning Val. A.S.	8:00, Thu.	Private homes	S. A. Hoynos, 1574 Sheridan, NE, 25084
	Youngstown	*Y'town A.C.	7:30, 1st Fri.	Homestead Pk. Pav'n.	F. W. Hartenstein, 905 Brentwood
OKLAHOMA	Tulsa	†*Tulsa A.S.	7:30, 1st Sat.	Private homes	R. L. Frossard, 4218 E. 25th Ave.
OREGON	Portland	†*Portland A.S.	8:00, 1st Mon.	Planetarium	H. J. Carruthers, 427 S. E. 61 Ave.
	Portland	†A.T.M. & Observers	8:00, 2nd Tue.	Private homes	Miss M. Edgar, 1626 S.E. Neholem (2)
PENNSYLVANIA	Beaver	†*Beaver Co. A.A.A.	8:00, 4th Tue.	Com'y Bldg., Tamaqui	Mrs. R. T. LuCaric, Box 463, Baden
	Millvale	A.A.A. Shaler T'ship	8:00, 3rd Fri.	Cherry City Fire House	Cliff Raible, Rebecca Sq. (9)
	Philadelphia	†A.A. of F.I.	8:00, 3rd Fri.	Franklin Institute	Edwin F. Bailey, LO 4-3600
	Philadelphia	†*Rittenhouse A.S.	8:00, 2nd Fri.	Franklin Institute	John Streeter, LO 4-3600
	Pittsburgh	†*A.A.A. of P'burgh	8:00, 2nd Fri.	Buhl Planetarium	D. F. Mathe, 105 Beedle Circle (27)
	Pottstown	Pottstown A.A.C.	7:30, Fri.	Public Library	W. E. Schultz, Public Library
RHODE ISLAND	Providence	Skyscrapers, Inc.	8:00, Mon. or Wed.	Ladd Observatory	Ladd Obs., Brown U., Jackson 1-5680
TENNESSEE	Chattanooga	†*Barnard A.S.	8:00, 3rd Fri.	Jones Observatory	A. H. Jones, 411 W. 21st St., 5-1646
	Nashville	*Barnard A.S.	7:30, 2nd Thu.	Vanderbilt Univ.	Miss J. Saffer, 446 Humphrey St. (10)
TEXAS	Dallas	†Texas A.S.	8:00, 4th Mon.	Various auditoriums	E. M. Brewer, 5218 Morningside, U6-3894
	Ft. Worth	†*Ft. Worth A.S.	8:00, 4th Fri.	Texas Christian U.	A. W. Mount, 4326 Birchman
	Port Arthur	†*Port Arthur A.C.	7:30, 2nd Thu.	5228 Fifth St.	F. T. Newton, 5213 Fifth St., 2-4807
UTAH	Salt Lake City	†*A.S. of Utah	8:00, 2nd Fri.	City and County Bldg.	Junius J. Hayes, 1148 East 1 S.
VERMONT	Springfield	†Springfield T.M.s	6:00, 1st Sat.	Stellafane	John W. Lovely, 27 Pearl St., 535-W
VIRGINIA	Norfolk	†*Norfolk A.S.	8:00, 2nd, 4th Thu.	Museum of Arts	A. Hustead, U.S. Weather Bureau, 21745
	Richmond	†*Richmond A.S.	8:00, 1st Tue.	Builders Exchange	J. S. Stith, 3125 Lamb Ave. (22)
WASHINGTON	Seattle	*Seattle A.A.S.	8:00, 2nd Fri.	Rainier Field House	F. J. Ritscher, 1631 N. 53 St.
	Spokane	†*A.T.M.s of Spokane	8:00, Last Fri.	Private homes	Chet Brown, W. 1117-14th
	Tacoma	Tacoma A.A.	8:00, 1st Mon.	Coll. of Puget Sd.	Dorothy E. Nicholson, 2816 N. Union Ave.
	Yakima	†*Yak. Am. Ast'mers	8:00, 2nd Mon.	Cha. of Comm. Bldg.	Edward J. Newman, 324 W. Yakima Ave.
WISCONSIN	Beloit	†Beloit A.S.	7:30, 2nd, 4th Wed.	YMCA Bldg.	K. E. Patterson, 318 Public Service Bldg.
	Madison	†Madison A.S.	8:00, 2nd Wed.	Washburn Obs.	Dr. C. M. Huffer, Washburn Obs.
	Milwaukee	†*Milw. A.S.	8:00, 2nd Mon.	Public Museum	E. A. Halbach, 2971 S. 52 St., W. Allis

STARS FOR MAY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of May, respectively; also, at 7 p.m. and 6 p.m. on June 7th and 23rd. For other times, add or subtract ½ hour per week. When facing north, hold "North" at the bottom; turn the chart correspondingly for other directions. The projection (stereographic) shows celestial co-ordinates as circles.